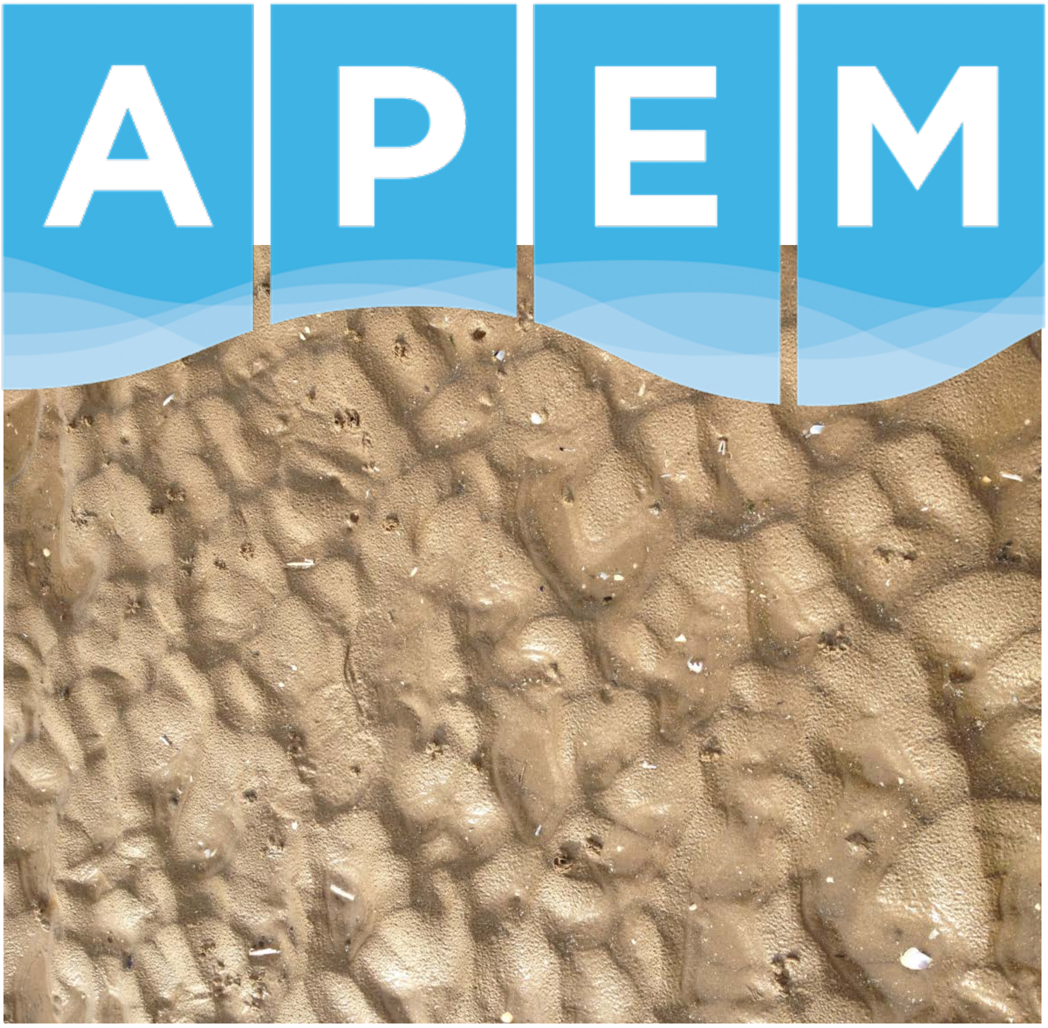

Dee Estuary SAC Condition Assessment Surveys 2015: Final Report

Natural England

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Cover Image: Rippled sand with *Arenicola marina* found along transect 12, New Brighton (outer sector) © APEM ltd

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Perez-Dominquez, R.P.D., Thomas, P.M.D., Neal, K. 2015. Intertidal sediment surveys of Dee Estuary and North Wirral Foreshore – Field Report. APEM Scientific Report 414287. Natural England, January 2016, 58 pp.

Executive summary

The Dee Estuary is located on the north-west British coastline between the Wirral Peninsula in England and north-east Wales. It covers an area of 14,000 ha and is one of the largest estuaries in the UK. Coastal processes are dominated by strong tidal streams and large sediment fluxes affecting the intertidal which are in turn of particular importance for the ecology and the morphology of the estuary.

The primary task of this study was to undertake dedicated survey work during the autumn of 2015 in order to derive high quality survey data on existing biotopes and supporting physical attributes to inform condition monitoring of Annex I habitat mudflats and sandflats not covered by seawater at low tide (H1140) (EUNIS code A2). Additional evidence from surface scrape samples (contaminants) and anthropogenic pressure information was collected to assist with assessment of change against historical evidence for each sub-feature with a preliminary condition assessment recommendation.

The sedimentary littoral sub-features targeted during the surveys were:

- Intertidal mud and sand flats
- Intertidal muddy sand biotopes
- Intertidal mud biotopes

Attributes that, subject to natural variation, should be used in the condition monitoring of the Dee Estuary SAC include measures of sub-feature extent, sediment character and distribution and community composition of characteristic biotopes. In addition a parallel high level evaluation was conducted on the presence of key benthic prey items for designated bird species bar-tailed godwit (*Limosa lapponica*), common tern (*Sterna hirundo*) and little tern (*Sterna albifrons*), as well as for intertidal feeders and wading bird species of the regularly occurring migratory birds and wintering assemblage.

Methods

The sampling design was informed by existing biotope distribution, aerial imagery and local knowledge of the team delivering the project. The survey was designed and implemented using a stratified transect-based approach with vertical transects identified within three predefined estuary sectors (outer – New Brighton, middle – West Kirby, and inner- Heswall) targeting the three sedimentary littoral sub-features of focus for this survey. This approach was decided as the best compromise between data quality, available resources and the size of the area to be surveyed. Field survey methods incorporate a combination of qualitative Phase I and quantitative WFD-compatible Phase II (0.01 m^2 hand corer) survey. All survey work was undertaken on foot as practicable at periods of spring low tides with active survey periods during daylight hours only.

Results

Particle size distribution in the Phase II coring samples indicated the presence of finer fractions and more well sorted sediments in the inner Dee Estuary compared to areas further out and the entire outer Dee sector which were dominated by sandy shores.

Sediment contaminants analyses indicated that most analytes were within the limits of the Canadian Interim marine Sediment Quality Guidelines (ISQG) and OSPAR contaminants in sediment guidelines. One sample collected just next to an outfall in the Heswall estuarine sector had elevated metal levels. No sample was found to exceed the ISQG Probable Effect Levels (PEL) for any of the reported analytes. Most contaminants were below OSPAR BAC (modelled background) or between BAC and the EAC/ERL (concentrations that are unlikely to give rise to unacceptable biological effects) levels. Some organic PAHs were reported over the OSPAR EAC/ERL in the Heswall estuarine sector and only a single PCB congener analysed exceeded the OSPAR EAC/ERL levels at all three estuarine sectors. The Redox Potential Discontinuity (RPD) layer was generally deper than 10cm, often not visible in the hand searches or core samples indicating well drained sediments and low organic carbon content. Inner estuary at areas with finer sediments have shallow RPDs.

A total of 10 intertidal soft sediment biotopes (EUNIS level 4 & 5) were identified across the transects surveyed. Most biotopes (eight in total), were identified to EUNIS level 5 or better (three sub-biotopes were recorded) and two areas were assigned to biotope complexes (EUNIS level 4). In addition to the main habitats of littoral sand and mud, an additional area of sublittoral muddy sand biotope (SS.SSa.IMuSa.EcorEns) was recorded at the lower edge of transect 11. The main habitats of the Dee Estuary SAC were characterised by littoral sand (LSa, 83.1% cover) followed by littoral mud (LMu, 15.8%). A small proportion of sites that bordered the intertidal exposed area during the large spring tides used for survey were assigned to sublittoral sand (SSa). Dominant biotope complexes were medium-fine (MoSa, 16.0%), fine (FiSa, 28.5%) and muddy sand (MuSa, 37.6%). Sandy mud (MEst, 15.2%) areas and littoral mud (UEst, 0.7%) areas were only recorded in the Heswall sector (inner estuary). Extensive areas of saltmarsh (LS.LMp.Sm) were found in the Heswall sector seaward from transects 0-4. This biotope complex was composed of mature and pioneer marsh and featured a complex morphology with numerous channels and creeks connecting sand and mud areas fronting the saltmarsh with upper vegetated areas found above the tidal limit. Finally, two additional broad habitat areas were recorded at the top of some transects, mixed coarse sediments and rock substrata; LR.MLR.BF.FspiB variant ([*Fucus spiralis*] on full salinity exposed to moderately exposed upper eulittoral rock) was recorded in the New Brighton sector (outer estuary) (near transects 13 and 14, estimated area 2.5 ha), and LR.FLR.Eph.BLitX (Barnacles and [*Littorina*] spp. on unstable eulittoral mixed substrata) was found on and around areas of artificial substrate in the West Kirby sector (middle estuary) (transects 5 and 6, estimated area 78.4 ha).

Number of taxa and number of individuals was greatest along the inner estuary sector transects with an average 10.75 taxa and 662 individuals per station (all 3 replicates combined). Species diversity decreased at the middle estuary and outer estuary sectors by 1.49 and 3.08 species, respectively. On average, total abundance halved at the middle estuary and decreased 15-fold at the outer estuary. The trend is likely to reflect the large amount of *Peringia ulvae* and Nematoda recorded within mud and muddy sand biotopes sampled at inner and middle estuarine sectors.

The only clear evidence of anthropogenic pressures within the EMS sandy shores was the collection of *Ensis* spp. (razor clams) at one transect in the New Brighton to Hoylake sector.

Assessment

A comparison was carried out between historical evidence and new data obtained in 2015, in an attempt to assess any change in habitat type that may have occurred since these studies were undertaken. It was not possible to make direct comparisons as different survey methods were used and quantitative data were not available for the full extent of the SAC area. Instead the assessment of the attributes “extent”, “sediment character” and “community composition” was done on available descriptions of life forms previously recorded and general character of the main three estuarine areas focus of this work.

The preliminary assessment considers that the following conservation objectives (CO) have been met:

- to maintain the extent of intertidal mudflats and sandflats;
- the reduction potential of sediments (depth of black anoxic layer) should not deviated significantly from the baseline;
- the level of contaminants in sediments should comply with Probable Effects Levels (PEL); and
- spatial distribution of muddy sand and mud biotopes in the muddy sand habitat should not deviate significantly from an established baseline.

Due to the difference in survey approaches it is not possible to make a specific recommendation for the following targets:

- average PSA parameters should not deviate significantly from an established baseline;
- no decrease in the variety of muddy sand and mud biotopes; and
- maintain availability of key prey items of preferred prey sizes.

1. Introduction

1.1 Dee Estuary

The Dee Estuary is located on the north-west British coastline between the Wirral Peninsula in England and north-east Wales. It covers an area of 14,000 ha and is one of the largest estuaries in the UK. Coastal processes are dominated by strong tidal streams and large sediment fluxes affecting the intertidal which are in turn of particular importance for the ecology and the morphology of the estuary.

Sedimentary habitat complexes range from littoral mud and muddy sand, to littoral medium-fine sand and barren littoral coarse sands, with muddier areas more dominant towards the upper estuary but are also present across the site under low energy hydrodynamic conditions. In more dynamic areas, gexposed to moderately exposed eulittoral boulders and cobbles that support *Sabellaria alveolata* biogenic reef as well as unstable mixed substrata. A range of invertebrate species, including worms such as *Scolelepis* spp. *Arenicola marina*, *Hediste diversicolor*, bivalves such as *Cerastoderma edule*, *Macoma balthica*, *Scrobicularia plana*, *Mytilus edulis*, amphipods such as *Bathyporeia pilosa* and *Corophium arenarium*, and isopods like *Eurydice pulchra* are typical components of the Dee faunal assemblage (NE & CCW 2010, NE & CCW 2010). *Hediste diversicolor*, *Macoma balthica*, *Cerastoderma edule* and *Scrobicularia plana* are typical from sheltered areas found on littoral sandy mud often at high densities. More dynamic areas tend to be barren or dominated by amphipods and worms characteristic of more mobile sand shores (NE & CCW 2010, CMACS 2011).

Historical changes such as canalisation of the River Dee and subsequent land reclamation in the 18th and 19th century for industrial complexes, farmland, residential uses and related infrastructure have decreased the extent of the intertidal area in particular across the upper reaches of the estuary (NCC 1978). However, the estuary still contains large expanses of intertidal mudflats and sandflats, the fifth largest area in the UK, which support an important benthic fauna and bird assemblage. Where land reclamation has not taken place the upper shores are characterised by saltmarsh grading into non-tidal brackish vegetation, in particular on the English side. Coastal processes are considered to be responsible for most of the deposition of sediments essential for maintaining the Dee Estuary mudflats, sandflats and saltmarsh (NCC 1978). The Dee Estuary is consequently a modified area. The main consequence of historical modifications on the intertidal soft sediment areas are a much reduced intertidal area and consequent alteration of local hydrological processes.

Human habitation and industrial uses are still important and the estuary supports a range of activities including recreation, navigation, fisheries, power stations, industry, and chemical plants. Despite current pressures the Dee is one of the most important estuaries in the UK and Europe in particular for migratory and wintering wildfowl and waders. It offers rich intertidal feeding grounds for these birds in particular the more stable intertidal areas and saltmarsh for roosting sites for waders and wildfowl at high tide. The Dee Estuary is also of particular importance as a staging area for migratory waterbirds (Natural England 2014, Holt et. al. 2015).

1.2 Background

The importance of natural habitats and wild species features within the Dee Estuary European Marine Site (EMS) has been recognised through the designation of Marine Protected Areas (MPAs) according to national and European legislation or other international agreements. The Dee Estuary EMS comprises the marine components of the Dee Estuary/Aber Dyfrdwy Special Area of Conservation (SAC) (Habitat Directive[1]), Special Protected Area (SPA) (Birds Directive[2]) and Ramsar site under the Convention of Wetlands of International Importance[3] (Figure 1). The SAC has been designated for its size and biological interest including saltmarshes, intertidal mudflats and sandflats, sand dunes, drift line vegetation and sea cliffs, the presence of petalwort *Petalophyllum ralfsii*, and sea lamprey *Petromyzon marinus* and river lamprey *Lampetra fluviatilis*. The SPA has been designated as it is used regularly by 1% or more of the Great Britain populations of: bar-tailed godwit *Limosa lapponica*; common tern *Sterna hirundo*; little tern *Sterna albifrons*; and sandwich tern *Sterna sandvicensis*. There are also a number of other migratory bird species of which 1% or more of the biogeographical populations are supported by the site as well as for its assemblage of approximately 120,726 waterbirds. The Dee Estuary Ramsar Site is designated because it supports internationally important wetlands and wetland species including internationally important numbers of wintering waterfowl and passage terns, and a nationally important assemblage of breeding birds. The entire Dee Estuary/Aber Dyfrdwy (13,680 Ha) and the associated features of interest were notified in 1984 as a Site of Special Scientific Interest (SSSI) (Wildlife and Countryside Act 1981[4]).

Natural England and Natural Resources Wales (formerly Countryside Council for Wales) provide advice on the conservation objectives for European marine sites in England and Wales, respectively and on the potential effect of any activity occurring within designated sites or in areas functionally connected with the sites. Regular site condition assessment is undertaken to determine whether the conservation status of designated features are being maintained and additionally to inform management plans affecting the site. Natural England's statutory responsibilities include advice on the implementation, and effective management of MPAs to safeguard natural ecosystems by protecting from degradation or by recovering from unfavourable conservation status.

Assessments use a number of attributes or measurable indicators of the perceived condition of the feature at the site. Each attribute is given a target value or Conservation Objective (CO) which is indicative of condition under the directives. Condition assessment is the evaluation of condition as evidenced by survey against the defined COs for designated feature(s) within the site. The COs for the Dee Estuary European marine site[5] are provided by the site Regulation 33(2) of the Conservation (Natural Habitats &c.) Regulations 1994 (Natural England & Countryside Council for Wales, 2010). Monitoring surveys are required to allow Natural England reporting of feature(s) condition every six years and are the basis for the management of activities within the site.

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[1] Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora.

[2] Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds.

[3] http://www.ramsar.org/

[4] http://www.legislation.gov.uk/ukpga/1981/69

[5] http://publications.naturalengland.org.uk/publication/2986296

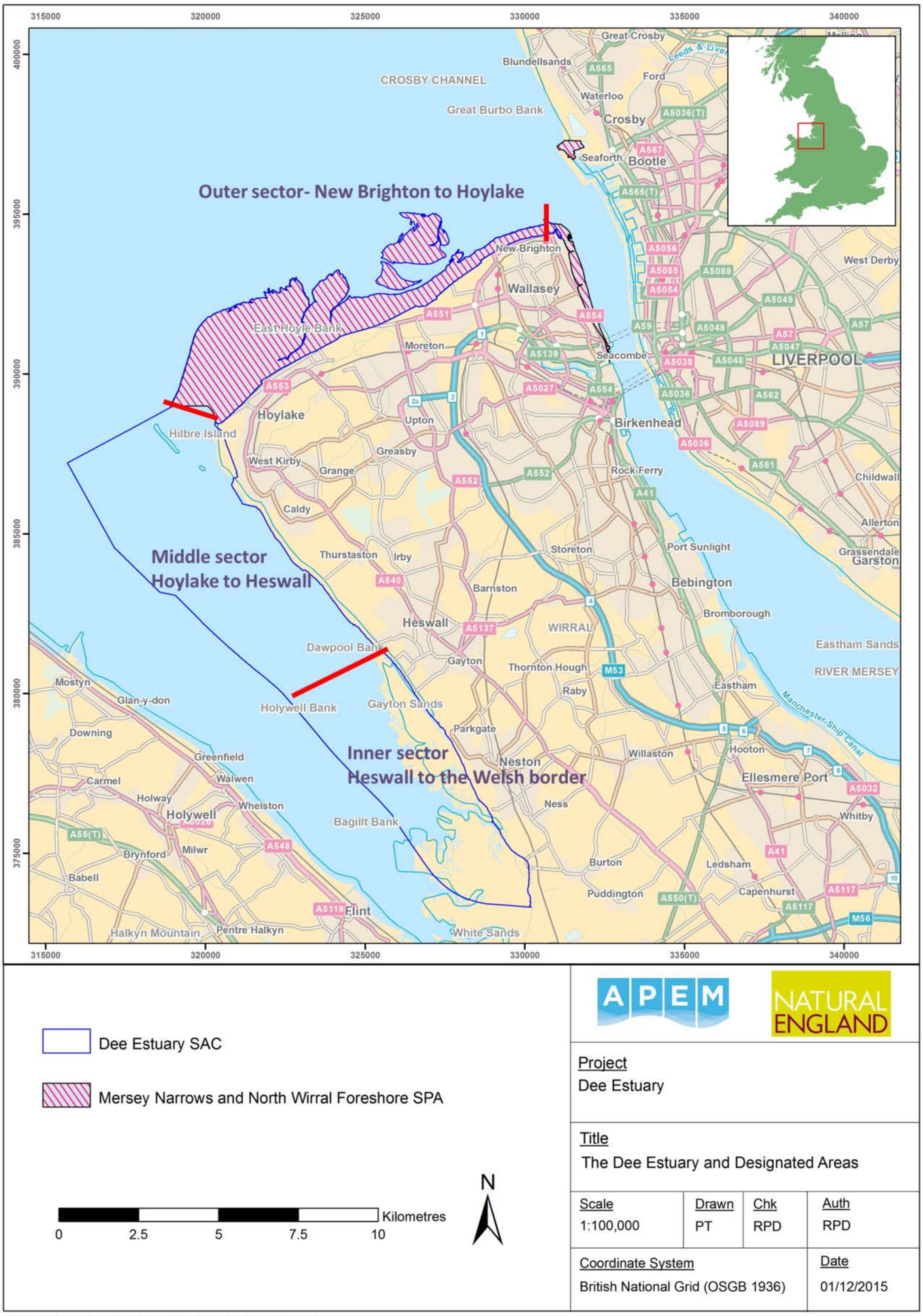

Figure 1 Extent of the English Dee Estuary / Aber Dyfrdwy SAC. The area of the Mersey Narrows and North Wirral Foreshore is highlighted. Estuary sectors are given.

1.3 Objectives

Natural England commissioned APEM Ltd to undertake an ecological survey to inform on the condition of intertidal soft sediment habitats within the English side of the Dee Estuary SAC as part of routine and long-term monitoring of this designated area. The work has been conducted in collaboration with the Centre for Marine & Coastal Studies (CMACS).

The primary task of this study was to undertake dedicated survey work during the autumn of 2015 in order to derive high quality survey data on existing biotopes and supporting physical attributes to inform condition monitoring of Annex I habitat mudflats and sandflats not covered by seawater at low tide (H1140) (EUNIS code A2). Additional evidence from surface scrape samples (contaminants) and anthropogenic pressure information was collected to assist with assessment of change against historical evidence for each sub-feature with a preliminary condition assessment recommendation.

The sedimentary littoral sub-features targeted during the surveys were:

- Intertidal mud and sand flats
- Intertidal muddy sand biotopes
- Intertidal mud biotopes

Attributes that, subject to natural variation, should be used in the condition monitoring of the Dee Estuary SAC include measures of sub-feature extent, sediment character and distribution and community composition of characteristic biotopes (Table 1).

In addition a parallel evaluation was conducted on the presence of key benthic prey items for designated bird species bar-tailed godwit (*Limosa lapponica*), common tern (*Sterna hirundo*) and little tern (*Sterna albifrons*), as well as for intertidal feeders and wading bird species of the regularly occurring migratory birds and wintering assemblage[6] (Table 2). This additional exercise was not part of the original project specification but was requested by Natural England at a later date. The intention for this work was to make a basic pre-assessment that can be used by Natural England alongside other evidence.

Table 1. Dee Estuary SAC attributes and associated targets for use in the definition of condition of the intertidal sandflat and mudflat features (NE & CCW 2010.

SAC Attribute (*Measure*)	Target (subject to natural variation)
Extent and variety of broad habitats and habitat complexes comprising each sub-feature	No significant decrease in extent of intertidal mudflats and sandflats from an established baseline.
Sediment character: - *Particle size analysis (PSA)*	 Average PSA parameters should not deviate

[6] Bird features or members of the Waterbirds Assemblage of the Dee Estuary SPA and the adjacent Mersey Narrows & North Wirral Foreshore SPA site are considered in the assessment. The recent conservation advice package for the site was used for reference. The site Reg. 33 explanatory information on bird features conservation objectives and references therein were used to scope relevant main prey species (Natural England, 2014).

SAC Attribute (*Measure*)	Target (subject to natural variation)
- Oxidation - reduction potential (depth of black anoxic layer)	significantly from an established baseline. Average black layer depth should not deviate significantly from an established baseline.
Toxic contamination of sediments *Concentrations of List I and List II substances under the Dangerous Substances Directive measured at a series of locations across the estuary*	Comply with Probable Effects Levels (PEL) derived for the interim sediment quality guidelines adopted by Environment Canada (Cole et al., 1999).
Distribution *Spatial distribution of **muddy sand biotopes** & **mud biotopes** measured along a series of fixed transects*	Spatial distribution of biotopes should not deviate significantly from an established baseline.
Community composition *Number of different **muddy sand biotopes** & **mud biotopes** measured by field visit*	No decrease in the variety of biotopes from an established baseline.

Table 2. Dee Estuary SPA supporting habitat attributes and associated targets for use in the definition of condition of designated bird features (Natural England 2014 and 2016).

SPA Attribute (*Measure*)	Target (subject to natural variation)
Supporting habitat: - food availability within supporting habitat	Maintain availability of key prey items of preferred prey sizes.

The main objectives of this project were to:

- Acquire high quality biological data of a suitable resolution that would allow a quantitative measure of each sub-feature attribute to be obtained;
- Obtain standardised faunal and botanical information for the target sub-features and associated communities of the Dee Estuary SAC;
- Make an assessment of change against previously collected data sets and where a baseline does not exist for a particular sub-feature attribute, produce a robust baseline against which future measures can be compared;
- Make a preliminary assessment of sub-feature condition by attribute on the basis of the data collected during this survey, where comparable historical data are available; and
- Document anthropogenic pressures occurring at the areas surveyed.

1.4 Existing Biotope information.

Previous surveys of the three Dee Estuary sub-features focus of this study have been limited to Phase I survey methods. Allen and Hemingway (2005) and CMACS (2011) provide the more comprehensive lifeform assessments although the recent work does not cover the entire footprint of the SAC. During the Phase I surveys, in-situ hand searches were used to assist with biotopes identification; a trowel-full of sediment was washed through a small sieve (1 mm mesh) so that infaunal invertebrates could be examined. Using a hand-lens it was often possible to identify fauna to genus level (e.g. *Bathyporeia* sp. or *Nephtys* sp.), some to species level particularly bivalves, but some groups, such as spionid polychaetes, could only be identified as far as family level. However, these data are qualitative appraisals and biotope-defining species have only been reported as general notes in the respective reports. Similarly sediment texture data available from these surveys are limited to the distribution of main sediment classes.

Existing Dee Estuary SAC CO have been defined indicating partial baselines derived from Allen and Hemingway (2005) commissioned by the former English Nature (now Natural England) and unpublished Intertidal Biotope Phase I Survey commissioned by the former Countryside Council for Wales in 2006. No PSA data or macrofaunal abundance datasets using Phase II methods are available.

1.4.1 New Brighton sector (outer sector) - New Brighton to Hoylake

Sedimentary biotopes along the outer sector running from New Brighton to Hoylake on the northern shore of the Wirral peninsula have been describe as primarily composed by littoral sands with areas ranging from barren sands (LS.LSa.MoSa.BarS) at the upper shore (Allen and Hemingway 2005). Lower on the shore profile and on the leeward side of existing groynes the amphipods *Bathyporeia pilosa* and *Corophium arenarium* have been recorded in littoral muddy sand (LS.LSa.MuSa.BatCare) and in muddier sediments the community have been reported to change to the polychaete *Hediste diversicolor* and bivalve *Macoma balthica* with oligocahetes and amphipods (LS.LMu.MEst.HedMac). CMACS (2011) reported wet rippled sands with *Arenicola marina* casts featuring *Macoma balthica* and *Cerastoderma edule* in hand searches characteristic species of two muddy sand biotopes LS.LSa.MuSa.MacAre/CerPo.

More exposed areas were less diverse and featured amphipods such as *Bathyporeia* sp., the gammarid *Haustorius arenarius* and robust polychaetes such as *Nepthys cirrosa* and *Scolelepis* spp. The sand mason worm *Lanice conchilega* biotope (LS.LSa.MuSa.Lan) has been recorded in large numbers along the low water mark (Allen and Hemingway 2005). Finally clay exposures have been recorded at the south-western end of East Hoyle Bank featuring piddock shells (*Barnea candida*) (Allen and Hemingway 2005), these exposures were not reported in the more recent survey by CMACS (2011). However, the CMACS surveys were conducted in autumn when survey opportunities with low spring tides were limited due to short days which means that clay features may not have been exposed by the tide on survey days.

1.4.2 West Kirby sector (middle sector) - Hoylake to Heswall

The middle sector between Hoylake and Heswall is located within the Dee Estuary. The upper shore contained barren sand areas (LS.LSa.MoSa.BarS) transitioning into pioneer (*Spartina*) saltmarsh (LS.LMp.Sm) (Allen and Hemingway 2005). Lower in the shore profile the intertidal are off West Kirby consisted of large and relatively uniform flats of sedimentary sandy habitat. These areas feature *Bathyporeia pilosa* and *Corophium arenarium* in littoral muddy sand (LS.LSa.MuSa.BatCare) grading into areas of slightly muddier wet rippled sands containing *Arenicola marina* and *Macoma balthica* as well as spionid polychaetes (LS.LSa.MuSa.MacAre) (Allen and Hemingway 2005). In raised well-drained and more mobile sands *Eurydice pulchra* (and some *Eurydice affinis*) along with *Bathyporeia pilosa* and *Ophelia* spp. (LS.LSa.MoSa.AmSco.Eur) were typical (Allen and Hemingway 2005; CMACS 2011). *Lanice conchilega* (LS.LSa.MuSa.Lan) and *Arenicola* beds, and mounds with very abundant *Cerastoderma edule* (possibly LS.LSa.MuSa.CerPo) have been reported at the lower shore.

Further into the estuary, the upper shore has been described as considerably muddier with very soft sediment to the south east of the man-made marine lake at West Kirby and with very abundant *Cerastoderma edule* beds formed into mounds (LS.LMu.MEst.HedMac) (CMACS 2011) and bordered by areas of *Mytilus edulis* (LS.LBR.LMus.Myt.Mu) along the main channel that runs form West Kirby towards Heswall (mainly on the east bank). Areas of rippled wet sand featured numerous *Arenicola marina*, *Cerastoderma edule*, *Peringia ulvae* (formerly *Hydrobia ulvae*) and *Corophium* spp. tubes typical of two of the muddy sand biotopes (LS.LSa.MuSa.CerPo/BatCare). *Arenicola* beds (LS.LSa.MuSa.MacAre) have been also described transitioning into softer muddy sediments with *Hediste diversicolor*, *Peringia ulvae*, *Corophium* spp., *Macoma balthica* and *Scrobicularia plana* (LS.LMu.MEst. HedMac/HedMacScr). Dense aggregations of the spionid polychaete *Pygospio elegans* forming regular hummocks in the sediment have ben described in this sector (CMACS, 2011).

1.4.3 Heswall sector (inner sector) - Heswall to the Welsh border

The inner sector from Heswall to Neston is described as considerably less diverse and contained a transition from sand and sandy mud biotopes similar to the Hoylake to Heswall sector (LS.LSa.MuSa.MacAre; LS.LSa.MuSa.CerPo/BatCare & LS.LSa.MoSa.AmSco.Eur) to significantly muddier biotopes (LS.LMu.MEst.HedMac & LS.LMu.MEst.HedMac/ HedMacScr) and extensive areas of established saltmarsh (LS.LMp.Sm). At lower shore elevations muddy sand habitats transitioned towards the main channel of the Dee Estuary into sandier areas including large sandflats featuring large sand waves similar to the outer estuary. These areas include amphipods *Bathyporeia pilosa* and robust polychaetes such as *Nepthys cirrosa* and *Scolelepis* spp. species characteristic of more exposed and less diverse locations (Allen and Hemingway 2005). Similarly drier areas are significantly less diverse or barren.

Starting from the northern edge of Heswall the saltmarsh (LS.LMp.Sm) becomes more extensive (i.e. broader) further into the estuary and up to the Welsh border. The area features a large number of channels and creeks into the core of the marsh. The areas fronting the marsh and along the main channels have been reported to contain significant numbers of *Hediste diversicolor* and the bivalve *Macoma balthica* (LS.LMu.MEst.HedMac) with occasional areas of *Arenicola marina* (LS.LSa.MuSa.MacAre) and the bivalve *Mya arenaria*.

2. Methods

The sampling strategy was based on a flexible stratified survey design informed by existing biotope distribution, aerial imagery and local knowledge of the team delivering the project. Field survey methods incorporate a combination of qualitative Phase I and quantitative WFD-compatible Phase II approaches. Surveys were conducted following best practice guidance including the Countryside Council for Wales (CCW) Handbook for Marine Intertidal Phase I mapping surveys (Wyn and Brazier 2001; Wyn et al. 2006), Marine Monitoring Handbook (Dalkin & Barnett 2001) and Common Standards Monitoring guidance (JNCC 2010 & 2004). The design was therefore based on a flexible adaptive approach implemented with standardised field methods which can be fully replicated in the future. For greater effectiveness Phase I and quantitative coring (partial Phase II) survey were conducted at the same time. The approach was agreed prior to the survey in consultation with Natural England.

The ensuing sections are descriptions of the method deployed and are intended to enable replication of the survey in the future, and assist the interpretation of the data and the analysis presented in the report. For a full description of the methods used and further survey details such as exact survey dates, access points, descriptions of equipment, safety considerations and survey logs please refer to the annexed project field report (Perez-Dominquez, et al. 2015) and data appendices.

2.1 Survey design

The survey was designed and implemented using a stratified transect-based approach with vertical transects identified within three predefined estuary sectors (outer – New Brighton, middle – West Kirby, and inner- Heswall) targeting the three sedimentary littoral sub-features of focus for this survey. This approach was decided as the best compromise between data quality, available resources and the size of the area to be surveyed. All survey work was undertaken on foot as practicable at periods of spring low tides with active survey periods during daylight hours only.

2.1.1 Pre-survey deskwork and location of sampling sites

The number of transect areas allocated to each estuary sectors were defined according to the following criteria:

1. Apparent habitat heterogeneity (estimated from the aerial photography and available historical data) with transects placed to cover as many biotopes as possible;

2. A proportionate split of the overall coverage of the habitat/biotope complexes of interest;
3. Provide good geographic spread throughout the site; and
4. Achievable with the resources and time available for the field investigations[7] and laboratory sample processing.

An initial biotope pre-visualisation using existing biotope data (Allen and Hemingway 2005; CMACS 2011) and high resolution georeferenced aerial imagery (acquired in 2013) to identify the survey areas was used to inform the stratified sampling protocol with estuary sectors (outer – New Brighton, middle – West Kirby, and inner- Heswall) and biotope information as the two main design elements. Final consideration before deciding the number and location of each of the transect areas was given to known anthropogenic pressures acting on the system and known bird feeding areas to allow for human pressures and bird supporting habitat to be accounted for in the interpretation of the data where relevant.

The initial proposal was refined through a consultation process with Natural England with the design of the survey initially proposed in a draft project plan presented and discussed at the project start up meeting (25.08.2015). After consultation, the agreed design resulted in the implementation of a transect-based survey with vertical transects identified within 15 search areas across the three predefined estuary sectors (five in each) targeting the three sedimentary littoral sub-features of focus for this survey (Table 1, Figure 3).

Once the final transect areas were agreed the placement of the coring stations was determined in order to provide a balanced geographical coverage of the three sub-features (target of the condition assessment) which are the focus of this work. Furthermore, the selected sampling sites (survey effort) were distributed across natural physical gradients (e.g. salinity gradient of the estuary (estuary sectors), exposure and shore elevation) and sub-features. The final array was therefore selected to ensure that coring stations were:

1. Randomly located along the predefined transects and within the broad sediment types identified through the pre-survey deskwork; and
2. Distributed across the transects with coring stations at mid and low shore (with an additional station at a high shore location, where appropriate).

The number of coring locations to assess per area was adjusted to 20 sites, a realistically achievable figure within the constraint of the area that had to be covered in the number of days available for field work. Finally, the surface scrape samples were located at five mid shore locations that had been previously sampled except one at the outer sector where no former data was available (Table 1).

This overall strategy to locate transects and coring stations maximised the level of statistical confidence at the feature level for any set level of effort (i.e. number of replicates available). The approach allows the interrogation of the data in multiple ways (e.g. estuary location, feature type, shore elevation, anthropogenic pressure gradients if relevant) and crucially the level of sampling standardisation required to ensure the data could be compared with historical data to assess direction of ecological change or to produce a robust baseline for

[7] Two field days per estuary sector were assigned for the field work.

future condition assessments. The approach was agreed prior to the survey in consultation with Natural England.

Table 3. Breakdown of Natural England approved sampling design.

	Estuary Sector		
	Outer (New Brighton)	Middle (West Kirby)	Inner (Heswall)
Number of transects (Phase I)	5	5	5
Number of quantitative coring stations (Phase II)	7	7	6
Surface scrape samples	1	2	3

2.1.2 Phase I Biotope Survey

Predefined survey transects were followed along their whole length where possible and visual inspection of sediments undertaken at regular intervals and/or at noticeable boundaries, including areas of sediment 20-30 m either side of the transect axis. Lower shore locations were visited two hours before or after low water during period of spring tides.

Biotopes were assigned in-situ by trained surveyors following standard guidance. Classifications were supported by in-situ hand searches and made to EUNIS level 4 or the highest possible level. Digital photographs were taken to allow quality assurance of the data recorded. The number of search points per transect was adjusted to a realistically achievable figure within the constraint of the area that had to be covered in the available low water window.

Throughout the Phase I survey, site descriptions were recorded in field notes. Specific notes were made in relation to any potential anthropogenic pressures at a given site which could influence intertidal ecology (e.g. pipelines, point source pollution, bait diggers) including their locations (marked with GPS where possible), the nature of the pressure, whether it seems to be continuous or intermittent etc., and a photograph taken where possible. Pressures were recorded as georeferenced target notes. Sediment descriptions collected in-situ included:

1. Texture description in accordance with the Folk sediment classification;
2. Presence of redox potential discontinuity (RPD) layer;
3. Evidence of nutrient enrichment and organic content;
4. Penetrability and sediment surface features (ripples, water pooling, debris, etc.);
5. Any other conspicuous species e.g. macroalgal species such as *Ulva* spp. lugworms casts etc. were recorded with estimates of abundance/cover;
6. Anthropogenic pressures; and
7. Target notes for features of interest including any invasive non-native species (INNS).

2.1.3 Phase II Quantitative Coring and Contaminant Survey

Quantitative coring (Phase II) was conducted at 20 predefined stations and was conducted at the same time as the above described Phase I survey. This approach focused on species composition and quantitative abundance data from specific transects suitable for the application of statistical analyses.

A total of three replicate core samples were collected at each station for the analysis of faunal composition with a 0.01 m^2 hand corer. A fourth identical core was collected for sediment Particle Size Analysis (PSA). Macrofaunal and PSA samples were stored until transportation to the designated third party analytical laboratory for analysis. The methodology described in the Marine Monitoring Handbook (Davies et al. 2001) was followed and all sediment samples were collected, stored and later analysed in accordance with the National Marine Biological Analytical Quality Control Scheme (NMBAQC) best practice guidance.

In addition, two sediment surface scrape samples were collected at five mid shore locations. Samples (each approximately 500 ml) were carefully collected from the top 1 cm of the sediment using appropriate collection methods to avoid sample cross contamination. Sample containers were provided by the designated analytical laboratory. Sediment surface scrape samples were later analysed for concentrations of metals and organic contaminants.

2.2 Data Analysis

On completion of the surveys, raw field data were transferred to electronic spreadsheets. This included a GPS waypoints log and all target notes included in the annexed survey completion report (Perez-Dominguez 2015), and photograph log (Appendix I). All GIS outputs were generated in ArcGIS v9.2 and metadata were produced in accordance with MEDIN standards in the MESH data exchange format (DEF).

Macrofaunal, Particle Size Distribution and contaminant datasets were provided by Natural England as Microsoft Excel® documents (Appendix II, III and IV). Raw 0.5φ size intervals data (by weight) and sample statistics were calculated in Gradistat by the analytical laboratory according to NMBQAC protocols (Mason 2015, Blott and Pye 2001). Surface sediment contaminant concentrations were normalised using OSPAR guidance (OSPAR 2008).

Macrofaunal abundance data were organised in a standard format to automatically create sample factors for use in the cluster and ordination analyses, e.g. estuarine sector, station and transect number, sediment classes, etc., to enable the data to be easily manipulated into the correct format for subsequent data processing tasks. Once the data had been compiled and transferred to the standard format, the faunal data were checked for errors and taxonomical inconsistencies by a senior taxonomist. This step ensures that all species names and linked physical data category were correct. Final Analytical Quality Control (AQC) of the data was carried out by the project manager to eliminate spelling or transcription mistakes, all relevant fields had been completed and the species were in order of their species directory code. Final automated consistency checks were also made to ensure data were complete and correct.

2.2.1 *Extent and distribution of Biotopes*

To create the biotope maps, field notes on biotope boundaries collected during the 2015 Phase I survey were compiled and mapped in ArcGIS onto high definition aerial imagery[8] overlaid with historical biotope information and 2015 Phase II (core samples) biotope results (ground truthing). The GPS waypoints for the corresponding coring station were subsequently used to create maps showing the exact locations and biotope identity of the cores that were taken during the 2015 Phase II survey (Appendix V). These data were then used to confirm the Phase I biotope assignations provided in the field notes and to update existing biotope information for the area. The goal of this exercise was to standardise the initial sub-feature mapping and align existing imagery with the Phase I and quantitative coring survey enabling an enhanced broad scale habitat survey over the entire area (100% coverage).

Phase I biotope assignations based on in-situ evidence alone, and Phase II assignations based on PSA and macrofaunal assemblage data were undertaken independently by different taxonomists. Habitat types were assigned according to JNCC's National Marine Habitat Classification for Britain and Ireland: Version 04.05 (Connor et al., 2004) taking into consideration species information, relative abundances, and substrate type. Phase I and Phase II biotope assignations were comparable, with most of the differences just requiring updating field assignations to more precise biotopes, as indicated by the smaller macrofaunal assemblage not assessed in the hand searches. In the case of further discrepancies, those Phase I biotopes characterised by large, more sparsely distributed infauna that can be easily seen in the field but generally underrepresented or missed by the cores (e.g. *Arenicola marina*), were not changed as the smaller macrofauna assemblage (Phase II data) can be very similar to those in other biotopes. The approach was implemented to improve the Phase I biotope mapping with the Phase II data, but not overriding what was assessed in the field. All mapping and interpretation of the aerial imagery were verified by a second GIS specialist and finally approved by the senior taxonomist to provide quality control and ensure the accuracy of the mapping.

The recorded biotope boundaries on the 15 transects surveyed along with observations of areas adjacent to the survey corridor (approximately 20-30 m either side) were assigned with high confidence. Beyond the immediate proximity of the transects, the biotope area was established using aerial photographs taken in 2013 by considering visually homogeneous areas indicating similar sediment type and controlling coastal processes. Biotope boundaries are considered to have lower confidence away from the transect areas resulting from possible sediment changes between 2013 and 2015 and presence of habitat mosaics where local factors create conditions different from surrounding areas. A degree of interpretation was required for the mapping and final boundaries were drawn according to best professional judgment and knowledge of the area. All assignments were verified by a second taxonomist to provide quality control and consistency in the assignments.

2.2.2 *Sample Univariate Statistics*

For the purposes of statistical analysis and for general description purposes, taxa qualifiers were ignored and data combined where required, e.g. juveniles and adults of the same

[8] The most recent aerial imagery available was collected in 2013. This represents a mismatch between the spatial information and the 2015 ground truthing data used in the biotope mapping.

species thus were considered together. Furthermore, the taxonomical resolution of the data set was standardised and entries of lower taxonomical resolution aggregated to higher levels if these were also recorded in the sample. For example if *Tellinoidea* (tagged as juveniles or sp. indet.) and individual species of the family *Tellinidae* (e.g. *Tellina tenuis*, *Tellina fabula*, *Macoma balthica*) were present in the same sample, the *Tellinoidea* entry would have been truncated. To retain quantitative information in the global analysis the recorded abundance for the truncated taxa was subsequently assigned to the higher taxonomical level species.

Sample univariate biological descriptors (richness and diversity indices) were calculated for each sample and station (summed replicates) in PRIMER v6 using default settings. The parameters calculated included:

- number of taxa (S);
- number of individuals (N);
- Shannon-Weiner Diversity Index ($\log_e$) (H')[9];
- Margalef's index of richness (d)[10]; and
- Simpson's Evenness (1-Lambda)[11].

This analysis also includes reporting summary values for physicochemical attributes such as sediment texture and contaminant data where available. Simple summary statistics such as mean and coefficient of variation were used to present and explore univariate trends. All calculations were performed in Microsoft Excel® 2010.

2.2.3 Community Analysis of Faunal Data

Multivariate statistical techniques were used to investigate the effect of survey design parameters (e.g. estuary sector, transect number, physical sediment data, shore elevation, etc.) on the faunal assemblage and to identify discriminating species of the biotopes identified in the analysis. All routines were computed in PRIMER v6 (Clarke and Gorley, 2006).

Trends in the physical data were analysed using Principal Component Analysis (PCA) after data normalisation. The PCA method uses Euclidean distance (dissimilarity between samples) to reduce the multidimensional physical dataset into linear combinations of component variables (sample parameters), simplifying the original complexity and revealing trends in the dataset. Two dimensional PCA configuration plots were used to visually illustrate the main physical variables driving the similarity between samples.

Community analysis was conducted on a Bray-Curtis resemblance (similarity) matrix. The data were log transformed before analysis. This type of transformation gives less abundant

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[9] H' is a widely used measure of diversity accounting for both the number of taxa present and the evenness of distribution of the taxa.

[10] d provides a measure of the number of species present for a given number of individuals. High values indicate more diverse assemblage.

[11] 1-λ is a dominance index derived from the probability of picking two individuals from a community at random that are from the same species. Simpson's dominance/evenness index ranges from 0 to 1 with lower values representing a more diverse community without dominant taxa.

species in the matrix increasing weight similar to more abundant species resulting in a greater emphasis on taxonomical similarities between samples. Cluster analysis was then carried out on the resemblance matrix to visualise the sample similarities based on their faunal composition. A simple hierarchical clustering dendrogram using group averaging was created to show the results of this clustering and indicates the level of similarity between each group of samples. The similarity profile test (SIMPROF) was implemented as part of the hierarchical clustering to identify sample groupings that share a significant group structure as opposed to random aggregation. In addition non-metric multidimensional scaling (nMDS) was used to represent sample similarities graphically. Samples that share similar communities will appear closer in the nMDS configuration plot than samples whose constituent assemblages are not related. A measure of the quality of the visual representation is given by the “stress” value, with lower stress indicating better representations.

Finally, Similarity Percentage analysis (SIMPER) was used to summarise discriminating species of the more abundant biotopes identified in the analysis. The analysis was conducted on log-transformed abundances. The SIMPER analysis provides the average percentage contribution from each species to the overall biotope assemblage and a measure of the variation expected within the replicate sites assigned to each biotope. Sample similarities within biotopes were further visualised with nMDS configuration plots.

3. Results

3.1 Physical environment

Particle size distribution in the Phase II coring samples indicated the presence of finer fractions and more well sorted sediments in the inner Dee Estuary (transects 1 to 7) compared to areas further out and the entire outer Dee sector (transects 8 to 14) which were dominated by sandy shores (Table 4).

Table 4. Dee Estuary SAC 2015 littoral sediment survey and summary statistics. Percentage distribution of sediment classes are given by weight (Wentworth scale class boundaries). Raw particle size distribution data is presented in Appendix III. Redox Potential Discontinuity (RPD) depth at the time of sampling is presented. Samples with no visible RPD on the core sample have been scored as greater than the coring depth (>15cm).

Transect	Station	RPD depth (cm)	Clay %	Silt %	Sand %	Gravel %	Median Particle Diameter (mm)	Mean Particle Diameter (mm)	Sorting Coefficient	Kurtosis
1	HWC1	10	0.99	3.64	95.3	0.04	0.146	0.156	0.593	1.070
2	HWC2	10	1.35	4.31	94.1	0.23	0.160	0.184	0.928	2.110
3	HWC3	1.0	19.3	51.2	29.5	-	0.023	0.044	2.220	0.720
4	HWC4	5.0	5.86	16.3	77.6	0.18	0.142	0.160	2.000	2.150
5	WKC1	7.5	9.49	28.6	61.9	-	0.090	0.091	2.150	0.809
5	WKC2	3.5	17.4	31.4	51.0	0.14	0.066	0.107	2.500	0.652
6	WKC3	10	5.90	18.4	74.8	0.88	0.218	0.300	2.260	2.120
6	WKC4	>15	-	-	100	-	0.277	0.291	0.462	0.965
7	WKC5	1.5	7.78	17.9	74.2	0.05	0.125	0.121	2.070	1.210
7	WKC8	>15	-	-	100	-	0.209	0.221	0.462	0.930
8	WKC6	7.5	-	-	98.9	1.11	0.246	0.369	0.484	1.010
8	WKC9	>15	-	-	100	-	0.213	0.225	0.459	0.927
9	WKC7	>15	-	-	99.7	0.26	0.211	0.238	0.483	0.885
10	NBC6	>15	-	-	99.8	0.16	0.253	0.281	0.488	1.000
10	NBC7	10	-	-	100	-	0.249	0.263	0.454	0.996
11	NBC4	>15	-	-	99.0	1.02	0.215	0.310	0.534	0.939
11	NBC5	>15	-	-	100	-	0.265	0.280	0.463	0.993
12	NBC3	>15	-	-	99.9	0.06	0.196	0.210	0.450	0.938
13	NBC2	>15	-	-	99.9	0.07	0.217	0.237	0.486	0.918
14	NBC1	>15	-	-	99.1	0.86	0.217	0.294	0.507	0.957

The first PCA axis separates medium to very fine sand and explains 53.3% of the overall variation (Figure 2). This first axis corresponds with an inner to outer estuary spatial ordination. The second PCA axis (21.0% of the variation explained) indicates a separation between coarse and fine sand fractions. Sediment texture and faunal composition for sand, muddy sandy and mud biotopes had in general remarkable good agreements confirming the important role of sediment texture as a community controlling physical factor (Figure 2). Detail on the faunal communities present is provided in Section 3.2.

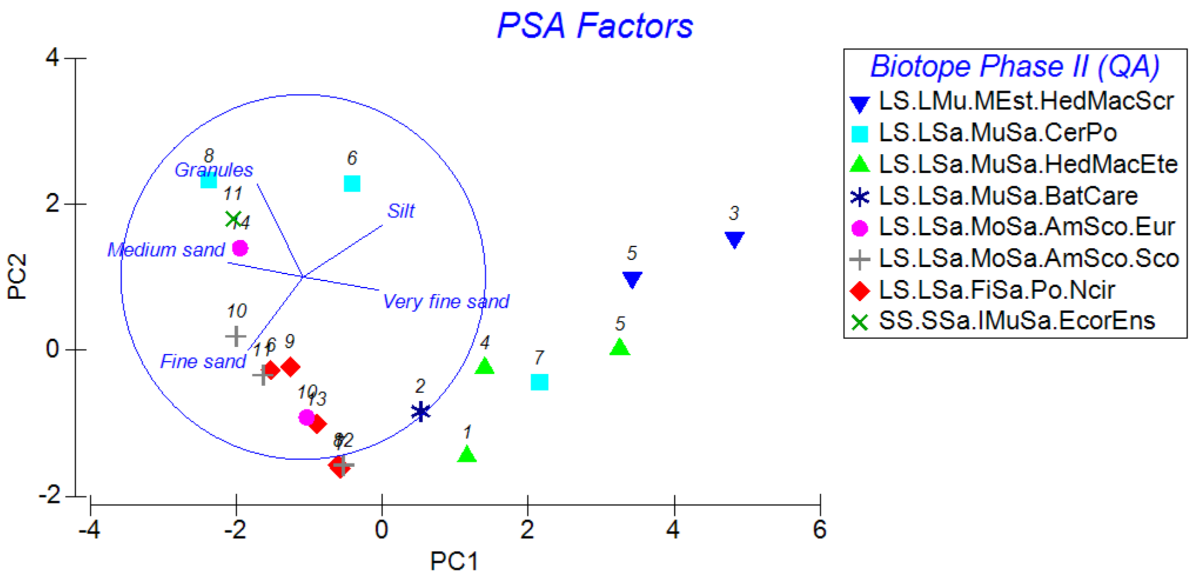


Figure 2. Dee Estuary SAC littoral sediment survey 2015 Principal Component Analysis (PCA) configuration plot illustrating similarities in sediment composition [12]. Symbols indicate the assigned Phase II biotope. The sample label indicates the transect. Equilibrium circle for the first two PCA axes and vectors for relevant sediment categories that contributed to the ordination graph are drawn. Transects 1 to 4 inner, 5 to 9 middle and 10 to 14 outer estuary.

The depth of the Redox Potential Discontinuity (RPD) layer was in general shallow in the inner estuary at areas of finer sediments high on the shore profile. Lower shore elevations dominated by sandy sediments consistently have deeper RPDs, generally below 10 cm when reported, indicating well drained sediments and low organic carbon content (Table 4). Middle and outer sectors are dominated by sandy shores with deep RPDs (Table 4).

Sediment contaminants analyses indicated that organic analytes were within the limits of the Canadian Interim marine Sediment Quality Guidelines (ISQG) (Cole et al. 1999) for all but Site 3 in the Heswall estuarine sector (Table 5A). This sample was collected just next to an outfall in the creek that runs behind the saltmarsh. Several inorganic analytes (mercury, chromium, copper, lead and zinc) exceeded the named guidelines in the Heswall sector. Chromium and arsenic was found over the recommended sediment thresholds in the West

[12] Interpretation note: The PCA plot shows the Euclidean distance between sites (samples). The vectors provide an indication of the gradients as they relate to the physical descriptors used in the ordination graph. Physical descriptors that significantly contribute to the ordination depicted in the PCA plot will have vectors that reach outside of the equilibrium circle.

Kirby sector. Arsenic was the only element exceeding the guidelines in the New Brighton sector. No sample was found to exceed the Probable Effect Levels (PEL) for any of the reported analytes.

A further assessment of sediment contaminants was carried out using OSPAR Co-ordinated Environmental Monitoring Programme (CEMP) published criteria (OSPAR 2010). The method uses the concept of sample enrichment respect to natural background concentrations (i.e. higher than expected value) for the type of sample matrix and accounts for expected natural variation. It uses normalisation and reference points in the prediction of effects levels. The contaminant concentrations were normalised using aluminium and organic carbon for metals and organic compounds, respectively. Most contaminants were below OSPAR BAC (modelled background) or between BAC and the EAC/ERL[13] (concentrations that are unlikely to give rise to unacceptable biological effects) levels (Table 5B). Only the metals mercury and zinc were above the EAC/ERL thresholds. West Kirby site 2 also showed high mercury level. The Heswall estuarine sector had the majority of organic PAHs exceedance with normalised values (3 analytes) suggesting a relative enrichment in samples with lower concentrations of organic carbon (normaliser). Only PCB – 118 exceeded the OSPAR guidelines at all three estuarine sectors.

Table 5. Dee Estuary SAC littoral sediment survey 2015 concentration of inorganic and organic substances used to assess sediment contamination. Analytes concentrations (Dry Weight) are presented by site sampled. Table A: Analytes included in the Canadian Interim marine sediment quality guidelines (ISQG) (Canadian Council of Ministers of the Environment 1992) are indicated in bold type (values exceeding the ISQG levels are highlighted with a grey cell shading). Raw analytical data are provided in Appendix IV. Table B: Normalised sediment contaminant concentrations using OSPAR guidance (OSPAR 2008). Only analytes with existing Background Assessment Concentrations (BAC) are indicated. Analytes with normalised values above background levels (BCA) are indicated in bold and those exceeding the Environmental Assessment Criteria or Upper assessment criterion (EAC/ERL) are indicated with a grey cell shading.

A (Canadian ISQG)	Estuary Section					
Raw values	Inner (Heswall)			Middle (West Kirby)		Outer (New Brighton)
	Site1	Site 2	Site 3	Site 1	Site 2	
Metals (mg/kg dry weight)						
Nitrogen (as N)	<200	1,330	2,920	<200	1,350	<200
Mercury	**0.0443**	**0.1310**	**0.2810**	**0.0066**	**0.1060**	**0.0117**
Aluminium §	23,300	42,600	63,300	12,500	34,100	14,600
Iron §	10,300	22,000	35,000	6,490	16,700	8,510
Arsenic §	**7.53**	**14.2**	**21**	**5.81**	**9.59**	**7.32**
Cadmium §	**0.201**	**0.24**	**0.389**	**0.016**	**0.15**	**0.027**
Chromium §	**24.7**	**64.5**	**86.6**	**23.9**	**54.4**	**24**
Copper §	**4.46**	**13.8**	**26.7**	**0.477**	**8.93**	**0.82**
Lead §	**18.5**	**34**	**58.8**	**9.33**	**24.7**	**9.65**
Lithium §	17.1	42.8	69	10.3	29.4	10.7

[13] BCA Background Assessment Concentration, EAC Environmental Assessment Criteria, ERL Effect Range-Low

A (Canadian ISQG)	Estuary Section					
Raw values	Inner (Heswall)			Middle (West Kirby)		Outer (New Brighton)
	Site1	Site 2	Site 3	Site 1	Site 2	
Manganese §	348	981	1,590	175	629	312
Nickel §	**8.48**	**21.6**	**35.2**	**3.43**	**15.3**	**5.26**
Zinc §	**107**	**126**	**242**	**23**	**82.9**	**21.8**
Organic Pesticides (µg/kg dry weight)						
Hexachlorobenzene	**<0.1**	**0.288**	**0.433**	**<0.1**	**0.219**	**<0.1**
Organic Solvent (µg/kg dry weight)						
Hexachlorobutadiene	<0.1	0.128	0.301	<0.1	<0.1	<0.1
Organic PAHs (µg/kg dry weight)						
Anthracene	**17.7**	**21.3**	**33.3**	**<1**	**13.2**	**<1**
Benzo(a)anthracene	**35.4**	**44.4**	**86.3**	**<1**	**30.5**	**1.29**
Benzo(a)pyrene	**35.3**	**68.2**	**128**	**<1**	**47.5**	**4.49**
Benzo(ghi)perylene	**20.3**	**68.9**	**135**	**<1**	**49.1**	**4.28**
Chrysene + Triphenylene	**40.6**	**65.7**	**120**	**<3**	**45.2**	**3.4**
Fluoranthene	**66.2**	**90.5**	**162**	**<1**	**59.9**	**4.88**
Indeno(1,2,3-c,d)pyrene	**21.9**	**59.7**	**125**	**<1**	**43.3**	**2.59**
Naphthalene	**6.6**	**24**	**44.3**	**<5**	**16.9**	**<5**
Phenanthrene	**16.0**	**53.1**	**89.9**	**<5**	**35.0**	**<5**
Pyrene	**58.0**	**89.9**	**157**	**<1**	**58.1**	**4.63**
Organic Brominated Flame Retardants (µg/kg dry weight)						
PBDE 153	<0.02	0.088	0.028	<0.02	<0.02	<0.02
PBDE 154	<0.02	0.025	0.042	<0.02	<0.02	<0.02
PBDE 99	<0.05	0.059	0.101	<0.05	<0.05	<0.05
PBDE 100	<0.02	0.021	0.038	<0.02	<0.02	<0.02
PBDE 47	<0.07	0.07	0.13	<0.07	<0.07	<0.07
PBDE 28	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Organic PCBs (µg/kg dry weight)						
PCBs, Total	**<0.7**	**1.897**	**3.956**	**<0.7**	**1.407**	**<0.7**
PCB - 028	**<0.1**	**0.382**	**0.762**	**<0.1**	**0.283**	**<0.1**
PCB - 052	**<0.1**	**0.167**	**0.325**	**<0.1**	**0.113**	**<0.1**
PCB - 101	**<0.1**	**0.225**	**0.475**	**<0.1**	**0.171**	**<0.1**
PCB - 118	**<0.1**	**0.321**	**0.687**	**<0.1**	**0.232**	**<0.1**
PCB - 138	**<0.1**	**0.257**	**0.511**	**<0.1**	**0.195**	**<0.1**
PCB - 153	**<0.1**	**0.366**	**0.783**	**<0.1**	**0.272**	**<0.1**
PCB - 180	**<0.1**	**0.179**	**0.413**	**<0.1**	**0.141**	**<0.1**
Organic biocide in anti-fouling (µg/kg dry weight)						
Tributyl Tin (as Cation)	**<4**	**<6**	**<6**	**<4**	**<5**	**<4**

§ HF Digest method.

B (OSPAR BAC & EAC/ERL)	Estuary Section					
Normalised values	Inner (Heswall)			Middle (West Kirby)		Outer (New Brighton)
	Site1	Site 2	Site 3	Site 1	Site 2	
Metals (mg/kg dry weight)						
Mercury	**0.10**	**0.15**	**0.22**	0.03	**0.16**	0.04
Arsenic	12.72	16.15	17.22	14.24	12.66	17.80
Cadmium	0.40	0.28	0.31	BC/LC§	0.21	0.02
Chromium	38.11	73.45	71.13	56.61	73.71	50.68
Copper	8.43	16.02	21.30	BC/LC§	12.63	0.38
Lead	**37.41**	**39.56**	**46.86**	**31.33**	**35.29**	**28.20**
Nickel	18.20	25.35	27.80	13.72	22.43	18.02
Zinc	**229.63**	**147.89**	**191.15**	92.02	121.56	74.67
Organic Pesticides (µg/kg dry weight)						
Hexachlorobenzene	<0.749	0.54	0.25	<1.25	0.07	<1.25
Organic PAHs (µg/kg dry weight)						
Anthracene	**132.49**	**40.04**	**19.09**	**<12.5**	4.25	**<12.5**
Benzo(a)anthracene	**264.97**	**83.46**	**49.48**	<12.5	9.81	**16.13**
Benzo(a)pyrene	**264.22**	**128.20**	**73.39**	<12.5	15.28	**56.13**
Benzo(ghi)perylene	**151.95**	**129.51**	77.41	<12.5	15.80	53.50
Chrysene + Triphenylene	**303.89**	**123.50**	**68.81**	**<37.5**	14.54	**42.50**
Fluoranthene	**495.51**	**170.11**	**92.89**	<12.5	19.27	**61.00**
Indeno(1,2,3-c,d)pyrene	**163.92**	**112.22**	71.67	<12.5	13.93	32.38
Naphthalene	**49.40**	**45.11**	**25.40**	**<62.50**	5.44	**<62.50**
Phenanthrene	**119.76**	**99.81**	**51.55**	**<62.50**	11.26	**<62.50**
Pyrene	**434.13**	**168.98**	**90.02**	<12.5	18.69	**57.88**
Organic PCBs (µg/kg dry weight)						
PCB - 028	**<0.749**	**0.72**	**0.44**	**<1.25**	0.09	**<1.25**
PCB - 052	**<0.749**	**0.31**	**0.19**	**<1.25**	0.04	**<1.25**
PCB - 101	**<0.749**	**0.42**	**0.27**	**<1.25**	0.06	**<1.25**
PCB - 118	**<0.749**	**0.60**	**0.39**	**<1.25**	0.07	**<1.25**
PCB - 138	**<0.749**	**0.48**	**0.29**	**<1.25**	0.06	**<1.25**
PCB - 153	**<0.749**	**0.69**	**0.45**	**<1.25**	0.09	**<1.25**
PCB - 180	**<0.749**	**0.34**	**0.24**	**<1.25**	0.05	**<1.25**

§ Measured concentration of the analyte was below its pivot normalisation value. Normalised concentration are expected to be below Background/Low Concentrations (BC/LC) levels.

3.2 Distribution of biotopes

The JNCC's correlation table (JNCC 2015) was used to assign EUNIS codes to each habitat type. The JNCC Classification hierarchy was applied to EUNIS levels as follows: EUNIS level 1 Environment > level 2 Broad habitats > level 3 Main habitats > level 4 Biotope complexes > level 5 Biotope > level 6 Sub-biotope. In general, the term 'habitat types' will be used where more than one level is discussed while terms for specific levels will be used where appropriate.

A total of 10 intertidal soft sediment biotopes (EUNIS level 4 & 5) were identified across the transects surveyed. Most biotopes (eight in total), were identified to EUNIS level 5 or better (three sub-biotopes were recorded) and two areas were assigned to biotope complexes (EUNIS level 4) (Table 6). In addition to the main habitats of littoral sand and mud, an additional area of sublittoral muddy sand biotope (SS.SSa.IMuSa.EcorEns) was recorded at the lower edge of transect 11. The main habitats of the Dee Estuary SAC were characterised by littoral sand (LSa, 83.1% cover) followed by littoral mud (LMu, 15.8%). A small proportion of sites that bordered the intertidal exposed area during the large spring tides used for survey were assigned to sublittoral sand (SSa). Dominant biotope complexes were medium-fine (MoSa, 16.0%), fine (FiSa, 28.5%) and muddy sand (MuSa, 37.6%). Sandy mud (MEst, 15.2%) areas and littoral mud (UEst, 0.7%) areas were only recorded in the Heswall sector (inner estuary) (Table 6, Figure 3).

Table 6. Dee Estuary SAC 2015 littoral sediment survey total estimated area of sandflats and mudflats biotopes. Biotopes are ranked by percentage of soft sediment intertidal area covered. The frequency value is the number of times the biotope was encounter on the footprint of a transect.

Biotope (JNCC 15.03 code)	EUNIS code (2007)	Biotope frequency	Area covered (ha)	% of total intertidal area
LS.LSa.FiSa.Po.Ncir	A2.2313	8	1,555.19	27.1
LS.LMu.MEst.HedMacScr	A2.313	6	871.36	15.2
LS.LSa.Mosa.AmSco.Sco	A2.2231	3	677.20	11.8
LS.LSa.MuSa.BatCare	A2.244	2	656.16	11.4
LS.LSa.MuSa.MacAre	A2.241	2	485.07	8.5
LS.LSa.MuSa.CerPo	A2.242	2	484.85	8.5
LS.LSa.Musa	A2.24	3	384.32	6.7
LS.LSa.MoSa.AmSco.Eur	A2.2232	3	242.51	4.2
LS.LSa.MuSa.HedMacEte	A2.243	2	144.98	2.5
SS.SSa.IMuSa.EcorEns	A5.241	2	115.59	2.0
LS.LSa.Fisa	A2.23	1	82.19	1.4
LS.LMu.UEst.Hed.Cvol	A2.3222	1	37.41	0.7
		Total	**5,736.82**	

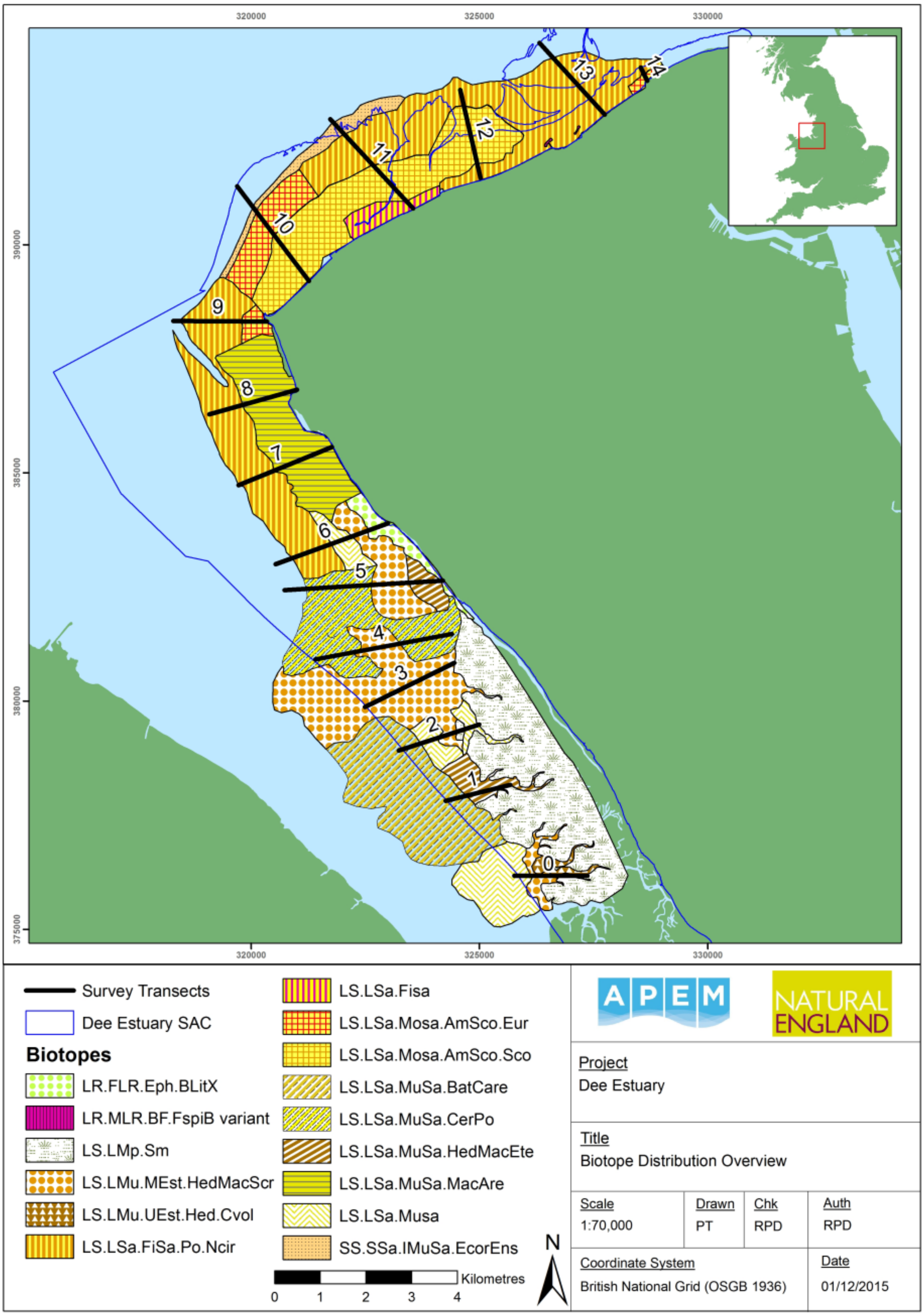


Figure 3. Dee Estuary SAC 2015 biotope distribution. Transects 0 to 4 inner, 5 to 9 middle and 10 to 14 outer estuary sectors. Detail transect maps are provided in Appendix V.

Extensive areas of saltmarsh (LS.LMp.Sm) were found in the Heswall sector seaward from transects 0-4. This biotope complex was composed of mature and pioneer marsh and featured a complex morphology with numerous channels and creeks connecting sand and mud areas fronting the saltmarsh with upper vegetated areas found above the tidal limit. Finally, two additional broad habitat areas were recorded at the top of some transects, mixed coarse sediments and rock substrata; LR.MLR.BF.FspiB variant ([*Fucus spiralis*] on full salinity exposed to moderately exposed upper eulittoral rock) was recorded in the New Brighton sector (outer estuary) (near transects 13 and 14, estimated area 2.5 ha), and LR.FLR.Eph.BLitX (Barnacles and [*Littorina*] spp. on unstable eulittoral mixed substrata) was found on and around areas of artificial substrate in the West Kirby sector (middle estuary) (transects 5 and 6, estimated area 78.4 ha) (Appendix V).

3.2.1 New Brighton sector - New Brighton to Hoylake

Transect 14 – LS.LSa.MoSa.AmSco (sub-biotope Eur) was found at the upper shore, with *Scolelepis* sp. and *Bathyporeia* spp. present. Below this, there were areas of wetter, rippled sand with standing water containing *Arenicola marina* (≈ 1-3 individuals/m^2). *Lanice conchilega* (≈ 1 individuals/m^2), *Tellina tenuis*, *Bathyporiea* spp. and *Nephtys* sp. were also found in hand searches. Areas below the wetter, rippled sand with standing water area featured low, dry banks and wet troughs with a few *Arenicola marina*, *Tellina tenuis*, *Nephtys* sp. and spionids within the wet troughs. The lower shore was LS.LSa.FiSa.Po.Ncir. *Tellina tenuis* was recorded at low density in hand searches.

Transect 13 – The upper shore was dominated by sand but contained some organisms more typical of muddy sand (*Littorina littorea* ≈ 2 individuals/m^2); the upper shore biotope was LS.LSa.FiSa.Po.Ncir with patches of LS.LSa.MuSa.MacAre, probably occurring in a mosaic where *Arenicola marina* was occasionally very abundant (≈ 20-30 individuals/m^2) on rippled medium sand patches (occasionally with abundant shell fragments). *Nephtys* sp. and shore crab *Carcinus maenas* were also recorded. Lower down the shore, *Lanice conchilega* was present but not enough (≈ 5 individuals/m^2) for the LS.LSa.MuSa.Lan biotope; the area was therefore likely to be LS.LSa.FiSa.Po.Ncir.

Transect 12 – Very similar to transect 13 with the upper shore containing a mix of LS.LSa.FiSa.Po.Ncir and LS.LSa.MuSa.MacAre. Lower down, the sand was drier than on transect 13; the biotope was LS.LSa.MoSa.AmSco (sub-biotope Sco). The lower shore was LS.LSa.FiSa.Po.Ncir with recorded presence of *Lanice conchilega*, *Arenicola marina* and *Ensis* spp. which made it likely to be SS.SSA.IMuSa.EcorEns at the edge of the intertidal. Approximately 25 people were seen collecting *Ensis* spp. (razor clams) from the end of the transect for around 500 m towards transect 11.

Transect 11 – The upper shore had very sparse fauna and was best classified at the level of LS.LSa.FiSa; further down the shore it became LS.LSa.MoSa.AmSco and then LS.LSa.FiSa.Po.Ncir. Areas of smooth sand were present here with shallow channels, razor clam (*Ensis* spp.) shells and some *Arenicola marina*. Rippled medium sand and extensive standing water with very abundant *Lanice conchilega* was found at lower elevations. SS.SSA.IMuSa.EcorEns occurred at the end of the transect.

Transect 10 – The upper shore here was rippled sand with standing water with *Peringia ulvae* on the sediment surface and *Arenicola marina* casts present in patches (≈ 5-10 individuals/m^2), but an otherwise sparse infauna. It therefore has some elements of LS.LSa.MoSa.AmSco (sub-biotope Sco) but also characteristics from some of the

LS.LSa.FiSa.Po and LS.LSa.MuSa biotopes. Further down, the shore was LS.LSa.MoSa.AmSco (sub-biotope Eur) but then lower down still there was sand with species from both LS.LSa.MuSa/FiSa biotopes. The lower shore was the same as transects 12 and 11 with SS.SSA.IMuSa.EcorEns.

Table 7. Biotopes present at the New Brighton sector (outer estuary). *Fucus spiralis* on exposed to moderately exposed upper eulittoral rock (LR.MLR.BF.FspiB) was also recorded on concrete groynes and other artificial hard structures[14].

Biotope (JNCC 15.03 code)	EUNIS code (2007)	Transect containing biotope	Biotope description
LS.LSa.FiSa.Po.Ncir	A2.2313	11, 12, 13 & 14	*Nephtys cirrosa*-dominated littoral fine sand
LS.LSa.MoSa.AmSco	A2.2231	10, 11 & 12	Amphipods and *Scolelepis* spp. in littoral medium-fine sand
LS.LSa.MoSa.AmSco.Eur	A2.2232	10 & 14	*Eurydice pulchra* in littoral mobile sand
SS.SSa.IMuSa.EcorEns	A5.241	10 & 11	*Echinocardium cordatum* and *Ensis* spp. in lower shore and shallow sublittoral slightly muddy fine sand
LS.LSa.FiSa	A2.23	11	Polychaete/amphipod-dominated fine sand shores

3.2.2 West Kirby sector - Hoylake to Heswall

Transect 9 – The upper shore was similar to the upper shore on transect 10, LS.LSa.MoSa.AmSco but with faunal characteristics of the sub-biotope Eur. Lower down there were again faunal characteristics of fine to muddy sands but it was likely to be dominated by LS.LSa.FiSa.Po.Ncir.

Transects 8 & 7 – There was little biotope variability in this section of the estuary in general. The upper and most of the midshore were very likely LS.LSa.MuSa.MacAre with some patches of LS.LSa.MuSa.CerPo. The anoxic layer[15] was as shallow as 5-7 cm depth across some flat, low relief ripples, medium/fine sand with areas of very sparse fauna. *Lanice conchilega* increased in density towards the lower shore, elevations across medium/fine sand areas with standing water, and LS.LSa.FiSa.Po.Ncir below it extended to the lower shore.

Transect 6 – At this location (and at Transect 5) the upper shore was bisected by a channel approximately 6 metres across and 0.3 metres deep with a predominantly sand bed. This channel originates at Parkgate and crosses the upper shore behind the saltmarsh, gradually broadening before crossing the shore near Thurstaston and emptying into the Dee. Above the channel, there was barren sand and a mixed coarse substrata (of mainly anthropogenic origin) biotope, probably LR.FLR.Eph.BLitX but in places ephemeral algae were dominant (LR.FLR.Eph.EntX). The upper shore (but below the channel) was mud with *Scrobicularia plana* characteristic of LS.LMu.MEst.HedMacScr as well as *Peringia ulvae* and *Corophium* sp. There were a couple of patches of cockles *Cerastoderma edule* on mixed substrata

[14] The Australasian barnacle *Austrominius modestus* an invasive non-native species (INNS) was found here.
[15] Assessed as sediment colour change marked by the Redox Potential Discontinuity (RPD) layer.

assigned to LS.LMx.Mx.CirCer. Lower on the shore the sediments became coarser until it was mainly muddy sand with *Corophium* sp., *Cerastoderma edule* and *Arenicola marina* (LS.LSa.MuSa) but with patches of *Mytilus edulis* (LS.LBR.LMus.Myt.Mu) along the main channel. The lower shore was sandier but still LS.LSa.FiSa.Po.Ncir extending to the main river channel as in transect 8 and 7 immediately to the north.

Transect 5 – This transect was similar to transect 6 but with the addition of the muddy sand biotope LS.LSa.MuSa.HedMacEte on the upper shore and patches of sparse *Arenicola marina* (≈ 1-2 individuals/m^2) below the channel which was classified as LS.LSa.MuSa.MacAre. On the intertidal flats *Scrobicularia plana* feeding marks (≈ 5 individuals/m^2), *Hediste diversicolor* and, *Peringia ulvae* (≈ 20 individuals/m^2) were found with *Peringia ulvae* density increasing and *Scrobicularia plana* decreasing toward the low shore. On the mid-shore there was rippled sand with *Arenicola marina* (≈ 5-10 individuals/m^2) and *Peringia ulvae* with patches of *Lanice conchilega*. The mid and lower shore were classified as LS.LSa.MuSa.CerPo in rippled sand with a low abundance of *Peringia ulvae*, increased abundance of *Arenicola marina* (≈ 10-15 individuals/m^2) in comparison to higher up the shore as well as *Mya arenaria* (≈ 5-10 individuals/m^2), *Nephtys* sp., surface *Cerastoderma edule* and *Macoma balthica*.

Table 8. Biotopes present at the West Kirby sector (middle estuary). Barnacles and *Littorina* spp. on unstable eulittoral mixed substrata (LR.FLR.Eph.BLitX) was also recorded at high shore locations (Figure 3).

Biotope (JNCC 15.03 code)	EUNIS code (2007)	Transect containing biotope	Biotope description
LS.LSa.FiSa.Po.Ncir	A2.2313	6, 7, 8, 9	*Nephtys cirrosa*-dominated littoral fine sand
LS.LMu.MEst.HedMacScr	A2.313	5 & 6	*Hediste diversicolor*, *Macoma balthica* and *Scrobicularia plana* in littoral sandy mud
LS.LSa.MuSa.MacAre	A2.241	7 & 8	*Macoma balthica* and *Arenicola marina* in littoral muddy sand
LS.LSa.MuSa.CerPo	A2.242	5	*Cerastoderma edule* and polychaetes in littoral muddy sand
LS.LSa.MuSa	A2.24	6	Polychaete/bivalve-dominated muddy sand shores
LS.LSa.MoSa.AmSco.Eur	A2.2232	9	*Eurydice pulchra* in littoral mobile sand
LS.LSa.MuSa.HedMacEte	A2.243	5	*Hediste diversicolor*, *Macoma balthica* and *Eteone longa* in littoral muddy sand

3.2.3 Heswall sector - Heswall to the Welsh border

Heswall Transect 4 – The upper shore was LS.LSa.MuSa.CerPo with patches of LS.LSa.MuSa.MacAre, and with LS.LMu.MEst.HedMacScr lower down and then back to the LS.LSa.MuSa.CerPo biotope with characteristics of MacAre and Lan. The bottom of the transect featured pioneer *Salicornia* saltmarsh on mud. Areas of rippled fine-medium sand with standing water with *Macoma balthica* in hand searches and *Arenicola marina* (≈ 3-5 individuals/m^2), a juvenile shore crab *Carcinus maenas* was recorded here. Wet rippled sand with numerous *Cerastoderma edule* also *Crangon* sp., *Bathyporeia* spp., *Arenicola marina* (≈ 3-5 individuals/m^2). Areas of spionid tubes were evident in wet sand below with *Lanice conchilega* (≈ 10 individuals/m^2). *Cerastoderma edule* was numerous, *Bathyporeia* spp. and *Crangon crangon* were also abundant. *Arenicola marina* (≈10 individuals/m^2) was present but no *Lanice conchilega* were found towards the end of the transect at the river channel.

Heswall transect 3 - The full length of this transect was LS.LMu.MEst.HedMacScr. Unlike other areas of estuary, the anoxic layer here was recorded as shallow as 1 cm in some patches of much softer mud with standing water. *Peringia ulvae* and *Scrobicularia plana* (up to ≈ 10 individuals/m^2) were recorded. Pools of standing water were observed to have *Scrobicularia plana* feeding scars at the bottom. Muddy sand was present up to the edge of the channel, just before the Welsh border. *Scrobicularia plana* feeding marks and siphon *Mya arenaria* holes (<1 individuals/m^2) were observed here.

Heswall Transect 2 – The upper shore was a mosaic of LS.LSa,MuSa biotope with LS.LMu.MEst.HedMacScr below it, then some saltmarsh, and back to a LS,LSa.MuSa biotope. The saltmarsh channel had rippled, wet, medium sand with standing water and evidences of microphytobenthos surface film. Hand searches at the edge of channel contained numerous spionids, *Macoma balthica*, *Scrobicularia plana* and *Hediste diversicolor*. Muddy sand bordering the saltmarsh changed to rippled wet medium sand with *Arenicola marina* (≈ 1-2 individuals/m^2) evident on sediment surface along with numerous *Peringia ulvae* and evidence of *Macoma balthica* and *Bathyporeia* spp. Other patches contained more *Arenicola marina* (≈ 10 individuals/m^2), *Macoma balthica* and *Cerastoderma* sp. At the Welsh border, the sand became rippled again and damp. Cockles, *Macoma balthica*, numerous *Corophium* sp. and *Bathyporeia* spp. were found in the hand searches.

Heswall Transect 1 – The transect featured LS.LSa.MuSa.HedMacEte close to the marsh edge and below LS.LSa.MuSa.BatCare in areas of drier rippled sand. Sand became wet, rippled with *Peringia ulvae* (≈ 10 individuals/m^2) and *Arenicola marina* (≈ 1 individuals/m^2) patches further down the shore. There was slightly less rippled, muddier sand with *Arenicola marina* (≈ 3-5 individuals/m^2) and very numerous *Corophium* sp. *Macoma balthica*, *Corophium* sp. and spionidae with some *Arenicola marina* were recorded at the Welsh border on wet medium rippled sand.

Heswall Transect 0 – Much of the upper shore here was LS.LMu.Uest.Hed.Cvol becoming LS.LMu.MEst.HedMacScr lower down and then a LS.LSa.MuSa biotope at the Welsh border. The areas bordering the saltmarsh featured a mud veneer on medium sand, and an anoxic layer 1 or 2 cm down, with few *Corophium volutator*. Muddy sand with numerous *Corophium volutator* and *Hediste diversicolor* was present bordering the drainage channel in the middle of the saltmarsh. Further towards the channel, the sediment changed to muddy sand and fine sand biotopes, featuring a smooth sediment surface with standing water, *Corophium* spp. and numerous, spionids present. No saltmarsh plants were present at the Welsh border.

Table 9. Biotopes present at the Heswall sector (inner estuary). Barnacles and *Littorina* spp. on unstable eulittoral mixed substrata (LR.FLR.Eph.BLitX) was also reported on high shore sites in the area.

Biotope (JNCC 15.03 code)	EUNIS code (2007)	Transect containing biotope	Biotope description
LS.LMu.MEst.HedMacScr	A2.313	0, 2, 3, 4	*Hediste diversicolor*, *Macoma balthica* and *Scrobicularia plana* in littoral sandy mud
LS.LSa.MuSa.BatCare	A2.244	1, 2	*Bathyporeia pilosa* and *Corophium arenarium* in littoral muddy sand
LS.LSa.MuSa.CerPo	A2.242	4	*Cerastoderma edule* and polychaetes in littoral muddy sand
LS.LSa.MuSa	A2.24	0, 2	Polychaete/bivalve-dominated muddy sand shores
LS.LSa.MuSa.HedMacEte	A2.243	1	*Hediste diversicolor*, *Macoma balthica* and *Eteone longa* in littoral muddy sand
LS.LMu.UEst.Hed.Cvol	A2.3222	0	*Hediste diversicolor* and *Corophium volutator* in littoral mud

3.3 Community analysis

3.3.1 Diversity results

Number of taxa (S) and number of individuals (N) was greatest along the inner estuary sector transects with an average 10.75 taxa and 662 individuals per station (all 3 replicates combined) (Table 10). Species diversity decreased at the middle estuary and outer estuary sectors by 1.49 and 3.08 species, respectively. On average, total abundance halved at the middle estuary and decreased 15-fold at the outer estuary. The trend is likely to reflect the large amount of *Peringia ulvae* and Nematoda recorded within mud and muddy sand biotopes sampled at inner and middle estuarine sectors (Table 11).

In general, the coefficients of variation suggest a reasonably good agreement between replicate samples (Table 10), and biotopes (Table 11) particularly given the fact that biotopes are assessed over a large geographical area. Similar results can be concluded from the nMDS grouping (i.e. similarity of replicates and biotope samples) (Figure 4). Biotope type explains diversity and dominance statistics well (Table 11). For example the LS.LSa.MuSa.CerPo, LS.LMu.MEst.HedMacScr and LS.LSa.MuSa.HedMacEte, biotopes typically associated with a more diverse polychaete/bivalve assemblage have the highest values of all littoral biotopes whilst the LS.LSa.FiSa.Po.Ncir a fine sand polychaete biotope associated with moderately exposed or sheltered beaches areas has the lowest values.

Table 10. Dee Estuary SAC 2015 littoral sediment survey diversity metrics by sampling station and estuary sector (bold). The values indicate average figues (3 replicate cores). Coefficents of Variation (CV%) are given in brackets.

Transect	Station	Phase II biotope assigned	Number of taxa (S)	Number of individuals (N)	Margalef's index of richness (d)	Shannon-Weiner Diversity Index (log_e) (H')	Simpson's Evenness (1-λ)'
1	HWC1	LS.LSa.MuSa.HedMacEte	9.67 (21.54)	1,757 (18.5)	1.17 (23.6)	1.30 (1.7)	0.67 (1.7)
2	HWC2	LS.LSa.MuSa.BatCare	10.67 (5.4)	407 (14.3)	1.62 (7.8)	1.25 (12.1)	0.59 (12.1)
3	HWC3	LS.LMu.MEst.HedMacScr	10.0 (10.0)	153 (13.3)	1.80 (12.9)	1.60 (16.8)	0.73 (16.2)
4	HWC4	LS.LSa.MuSa.HedMacEte	12.67 (16.4)	331 (17.9)	2.02 (15.0)	1.56 (9.8)	0.68 (9.7)
		HW - inner	**10.75 (16.9)**	**662 (99.8)**	**1.65 (23.5)**	**1.43 (15.4)**	**0.67 (12.5)**
5	WKC1	LS.LSa.MuSa.HedMacEte	12.00 (8.3)	171 (25.7)	2.16 (2.8)	1.84 (4.7)	0.79 (5.4)
5	WKC2	LS.LMu.MEst.HedMacScr	13.67 (4.2)	581.7 (17.6)	2.00 (3.6)	1.78 (7.6)	0.74 (6.2)
6	WKC3	LS.LSa.MuSa.CerPo	19.34 (14.9)	1,436 (22.6)	2.53 (13.1)	1.85 (7.2)	0.75 (7.0)
6	WKC4	LS.LSa.FiSa.Po.Ncir	3.34 (34.7)	8.0 (54.1)	1.18 (40.6)	1.12 (33.0)	0.78 (13.0)
7	WKC5	LS.LSa.MuSa.CerPo	13.67 (18.4)	586.4 (32.8)	2.0 (14.4)	1.29 (10.3)	0.64 (2.9)
7	WKC8	LS.LSa.FiSa.Po.Ncir	4.34 (74.2)	196 (137.5)	0.97 (37.4)	0.56 (84.1)	0.40 (97.1)
8	WKC6	LS.LSa.MuSa.CerPo	9.00 (0)	222 (38.6)	1.53 (11.6)	1.13 (23.3)	0.53 (24.0)
8	WKC9	LS.LSa.FiSa.Po.Ncir	4.34 (74.2)	9.4 (62.1)	1.45 (61.2)	1.13 (51.2)	0.73 (11.5)
9	WKC7	LS.LSa.FiSa.Po.Ncir	3.67 (15.8)	14.4 (97.1)	1.42 (47.5)	1.03 (37.7)	0.71 (49.9)
		WK - middle	**9.26 (62.4)**	**358 (129.7)**	**1.69 (36.4)**	**1.30 (38.7)**	**0.67 (29.8)**
10	NBC6	LS.LSa.MoSa.AmSco.Sco	8.34 (6.9)	93.4 (25)	1.64 (11.4)	1.20 (36.3)	0.53 (41.2)
10	NBC7	LS.LSa.MoSa.AmSco.Eur	5.34 (21.7)	46.7 (17.6)	1.14 (27.6)	1.28 (12.0)	0.70 (6.1)
11	NBC4	SS.SSa.IMuSa.EcorEns	13.34 (24.1)	58.7 (17.4)	3.02 (20.8)	1.88 (17.7)	0.79 (12.2)
11	NBC5	LS.LSa.MoSa.AmSco.Sco	6.00 (16.7)	31 (18.5)	1.46 (13.4)	1.22 (15.1)	0.61 (21.7)
12	NBC3	LS.LSa.MoSa.AmSco.Sco	6.00 (16.7)	15.4 (21.6)	1.86 (22.8)	1.52 (14.0)	0.79 (7.6)
13	NBC2	LS.LSa.FiSa.Po.Ncir	6.00 (16.7)	11.4 (11.1)	2.09 (25.1)	1.64 (14.7)	0.86 (9.0)
14	NBC1	LS.LSa.MoSa.AmSco.Eur	8.67 (35.3)	57.4 (27.9)	1.89 (33.1)	1.35 (12.0)	0.66 (7.8)
		NB - outer	**7.67 (40.3)**	**44.9 (64.8)**	**1.87 (36.4)**	**1.44 (22.5)**	**0.70 (20.4)**

Table 11. Dee Estuary SAC 2015 littoral sediment survey diversity statistics by biotope. Biotopes are ranked in order of speceis diversity. Values indicate average figures. Coefficents of Variation (CV%) are given in brackets.

Biotope Assigned	Number of taxa (S)	Number of individuals (N)	Margalef's index of richness (d)	Shannon-Weiner Diversity Index (log_e) (H')	Simpson's Evenness (1-λ)
LS.LSa.MuSa.CerPo	14.0 (34.8)	748 (74.3)	2.02 (24.6)	1.42 (25.6)	0.64 (18.2)
SS.SSa.IMuSa.EcorEns	13.3 (24.1)	58.7 (17.4)	3.02 (20.8)	1.88 (17.7)	0.79 (12.2)
LS.LMu.MEst.HedMacScr	11.8 (18.0)	367 (61.7)	1.90 (9.9)	1.69 (12.6)	0.74 (11.0)
LS.LSa.MuSa.HedMacEte	11.5 (18.1)	753 (98.1)	1.78 (28.6)	1.56 (16.0)	0.71 (10.1)
LS.LSa.MuSa.BatCare	10.67 (5.4)	407 (14.3)	1.62 (7.8)	1.25 (12.1)	0.59 (12.1)
LS.LSa.MoSa.AmSco.Eur	7.00 (39.3)	52 (26.5)	1.52 (40.1)	1.32 (11.1)	0.68 (7.2)
LS.LSa.MoSa.AmSco.Sco	6.78 (20.6)	46.6 (78.4)	1.65 (18.5)	1.31 (22.9)	0.64 (27.0)
LS.LSa.FiSa.Po.Ncir	4.34 (47.5)	47.9 (296)	1.42 (45.6)	1.09 (46.2)	0.69 (37.9)

3.3.2 Multivariate analysis

Differences in macrofaunal assembalge were investigated using ordination analysis. The distribution of samples in the ordination plot reflects the selection of sites across the main expected biotopes; as such the assessment mainly provides information on community (dis-) similarities rather than a robust spatial assessment. Nevertheless, inner estuary samples show a very close similarity in assembalge composition. These core samples were assigned to two closely related muddy sand biotopes LS.LSa.MuSa.HedMacEte, LS.LSa.MuSa.CerPo, and the sandy biotope LS.LMu.MEst.HedMacScr (Figure 4A, Figure 5). Greater assemblage variability (five additional biotopes) was found at the middle and outer estuarine sectors sampled (Figure 4B, Figure 5).

SIMPROF analysis (999 simulations, 5% significance level) sugested a possible four- or five-cluster structure in the multivariate dataset which corresponded well with existing intertidal biotope definitions (Figure 5). A single location assigned to SS.SSa.IMuSa.EcorEns, a subtidal biotope, was clearly distinct to all other sites sampled.

These results appear to suggest that, as expected, physical conditions such as freshwater influence and sediment dynamics or exposure are likely to affect the biotope distribution by controlling the composition of the macrofaunal assemblage. This conclusion have been determined based on the current understanding of marine sediments in the area, the observed distribution of biotopes across the estuary sectors and general marine sediment ecology.

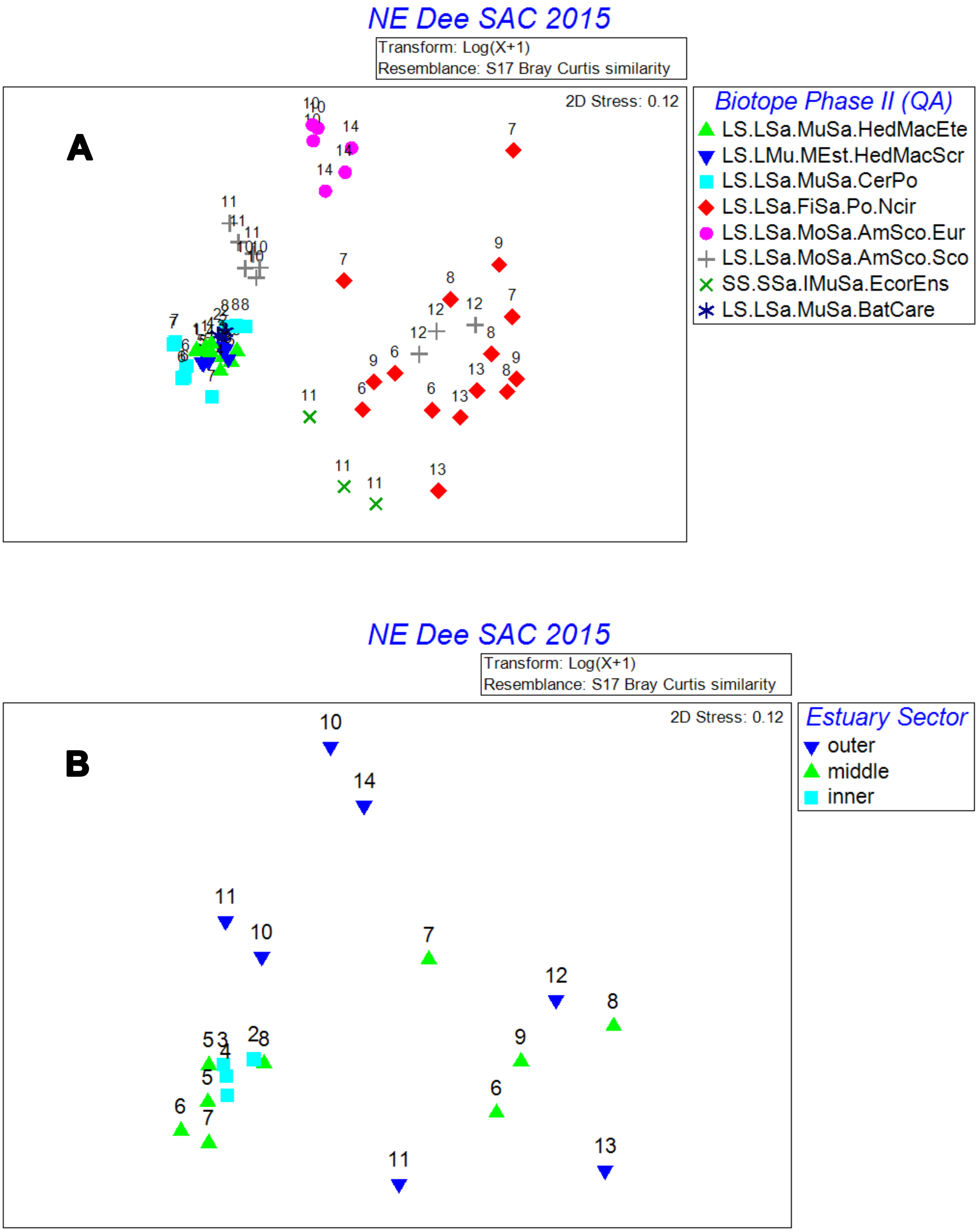


Figure 4. Dee Estuary SAC 2015 littoral sediment survey two dimensional nMDS ordination plots. The sample number gives the order of the sampling transects with respect to the upper-most site (number 1) and symbols indicate A biotope allocation and B estuarine sector.

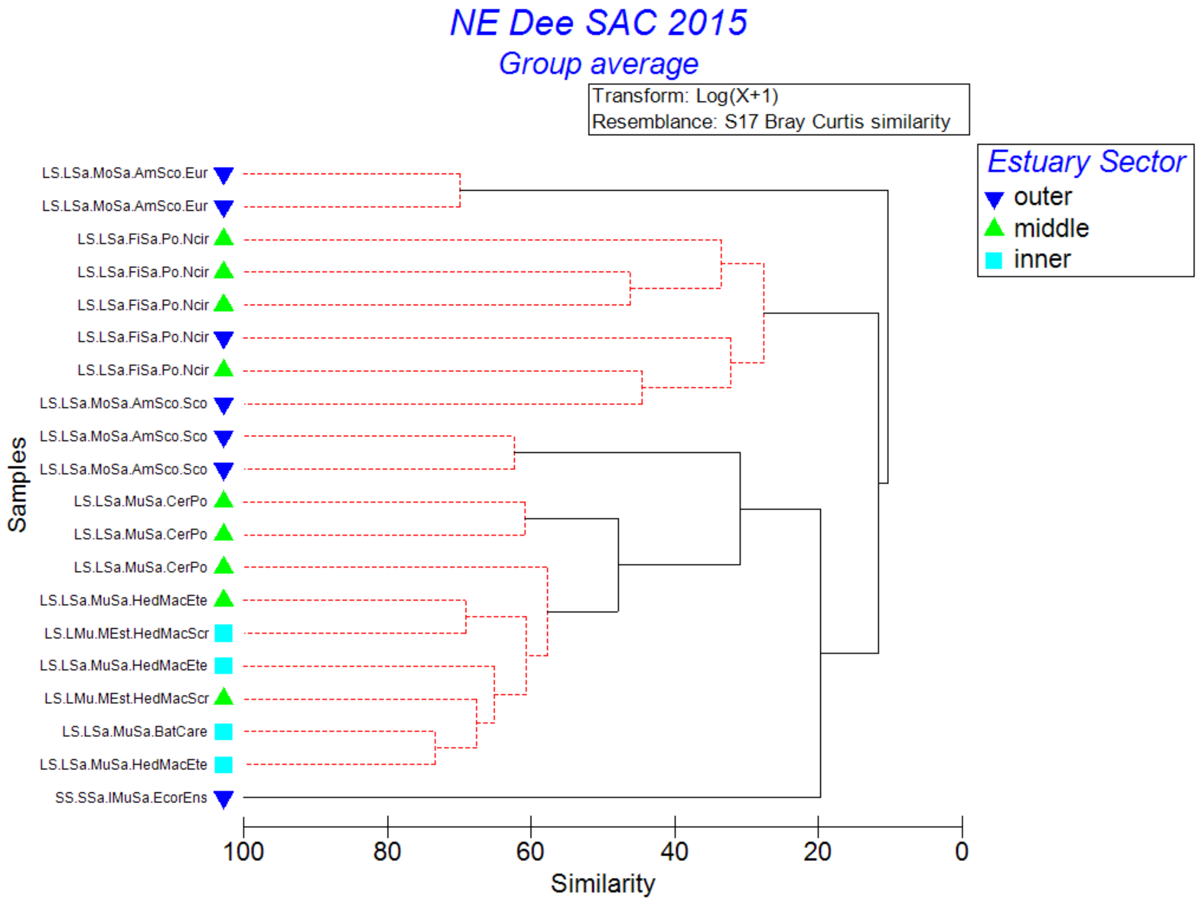


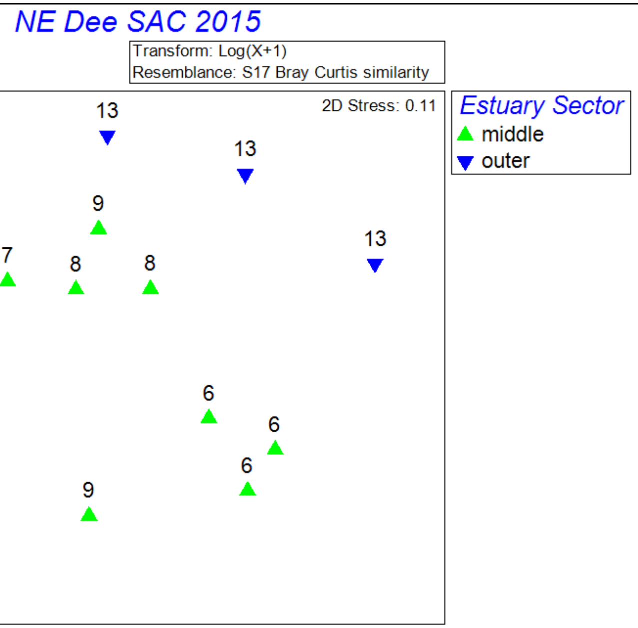
Figure 5. Dee Estuary SAC 2015 littoral sediment survey ordination diagram representing similarity between faunal communities. The samples are coded by estuarine sector.

Phase I biotopes LS.LSa.MuSa.MacAre (8.5% cover), LS.LMu.UEst.Hed.Cvol (0.7% cover) were not found in the Phase II coring survey. The small macrofaunal assemblage within LS.LSa.MuSa.MacAre, however, was represented by biotopes LS.LSa.MuSa.HedMacEte and LS.LSa.MuSa.CerPo sampled in the middle and inner estuary. No station was placed within LS.LMu.UEst.Hed.Cvol and consequently no quantitative assemblage information for this biotope was acquired.

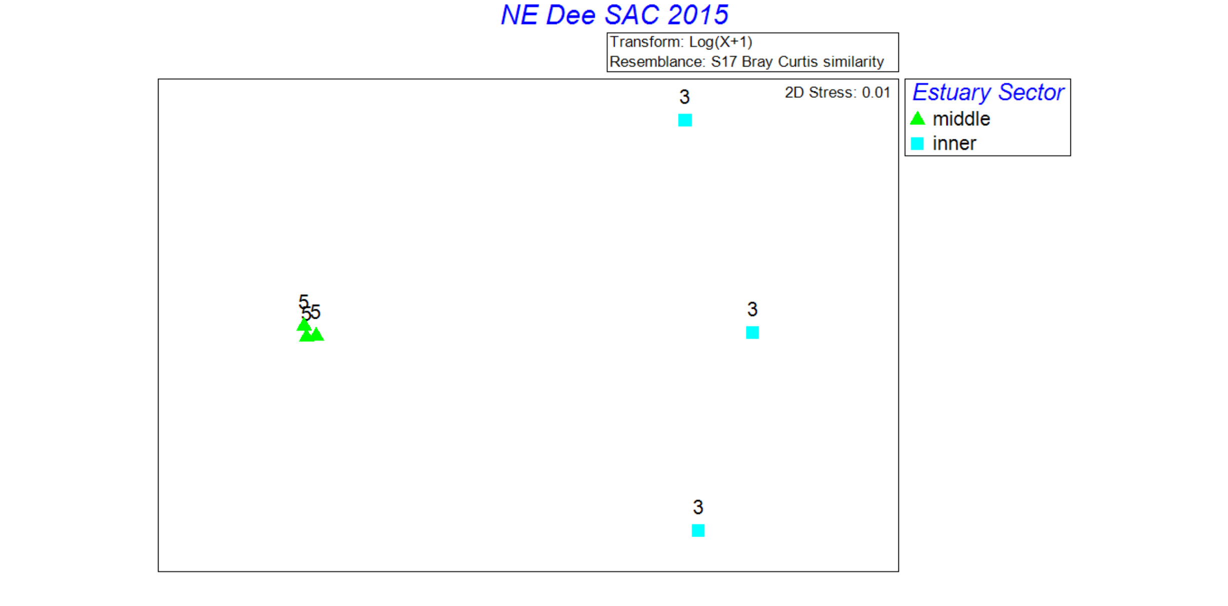
Similarity Percentage analysis (SIMPER) was used to summarise discriminating features of the more abundant biotopes identified in the analysis and a measure of the variation expected within the replicate sites assigned to each biotope (Table 12). Visual examination (MDS diagrams) suggested that a degree of community variation in LS.LSa.FiSa.Po.Ncir and LS.LMu.MEst.HedMacScr could be associated to estuarine areas. LS.LSa.FiSa.Po.Ncir also had the lowest average community similarity of all biotopes assessed (29.14%: N=15) followed by LS.LSa.MoSa.AmSco (Sco/Eur sub-biotopes) (30.16%: N=15). As similarity between replicate samples was generally good, then a degree of community variation across sites can be expected for these two biotopes. The Bray-Curtis index was used to provide the similarity values for the ordinations. To prevent bias due to low replication, the MDS method was applied only to those biotopes with four or more samples.

Table 12. Dee Estuary SAC littoral sediment survey 2015 SIMPER analysis table providing abundance of diagnostic species, variability and contribution to the group similarity. The table shows higher-contributing species to the cumulative similarity percentage (a cut-off value of 90% was used). N indicates the number of sampling stations in which the biotope was found. The insert MDS ordination diagram shows the relative similarities for all samples assigned to the biotope. The sample number and symbols are explained in Figure 4.

Biotope LS.LSa.FiSa.Po.Ncir	Average similarity: 29.14				N=15
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Nephtys cirrosa	1.05	17.12	1.23	58.76	58.76
Spio martinensis	0.57	4.70	0.56	16.14	74.91
Bathyporeia sarsi	0.50	2.81	0.37	9.65	84.55
NEMATODA	0.89	2.01	0.30	6.91	91.46

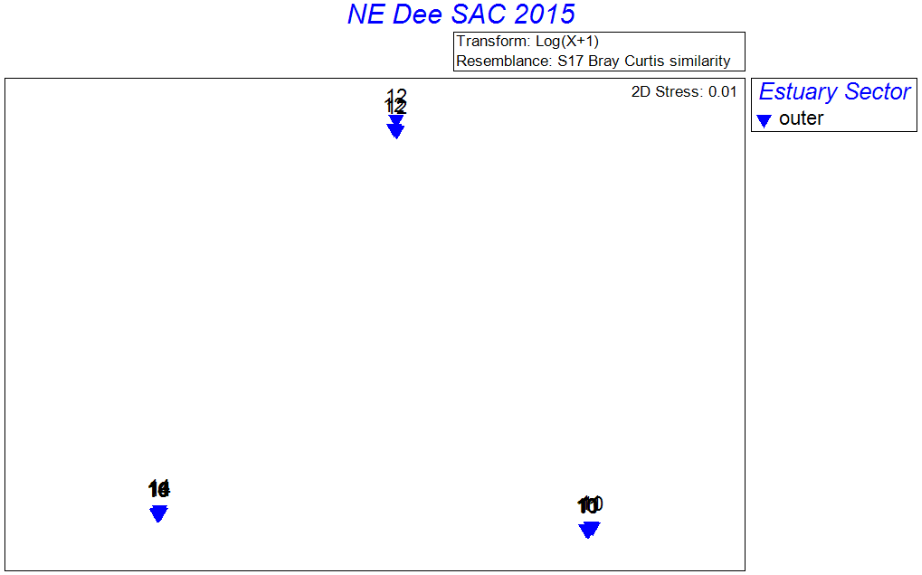


Biotope LS.LMu.MEst.HedMacScr	Average similarity: 70.42				N=6
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Peringia ulvae	4.77	14.21	5.62	20.18	20.18
NEMATODA	3.87	11.67	6.80	16.57	36.75
Pygospio elegans	3.30	10.86	5.09	15.42	52.17
Macoma balthica	3.40	10.67	6.06	15.15	67.32
Scrobicularia plana	1.96	5.96	6.19	8.46	75.78
Enchytraeidae	2.39	5.13	1.87	7.29	83.08
Eteone longa	1.69	3.57	2.47	5.08	88.15
Hediste diversicolor	0.88	1.93	1.08	2.73	90.88

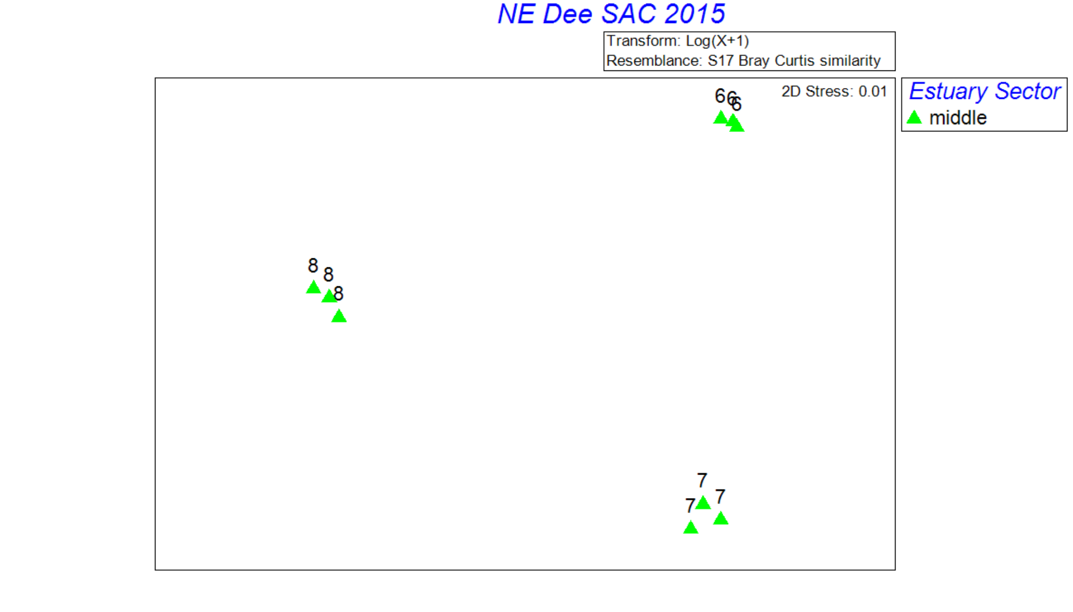


Biotope LS.LSa.MoSa.AmSco.Sco/Eur | **Average similarity: 30.16** | **N=15**

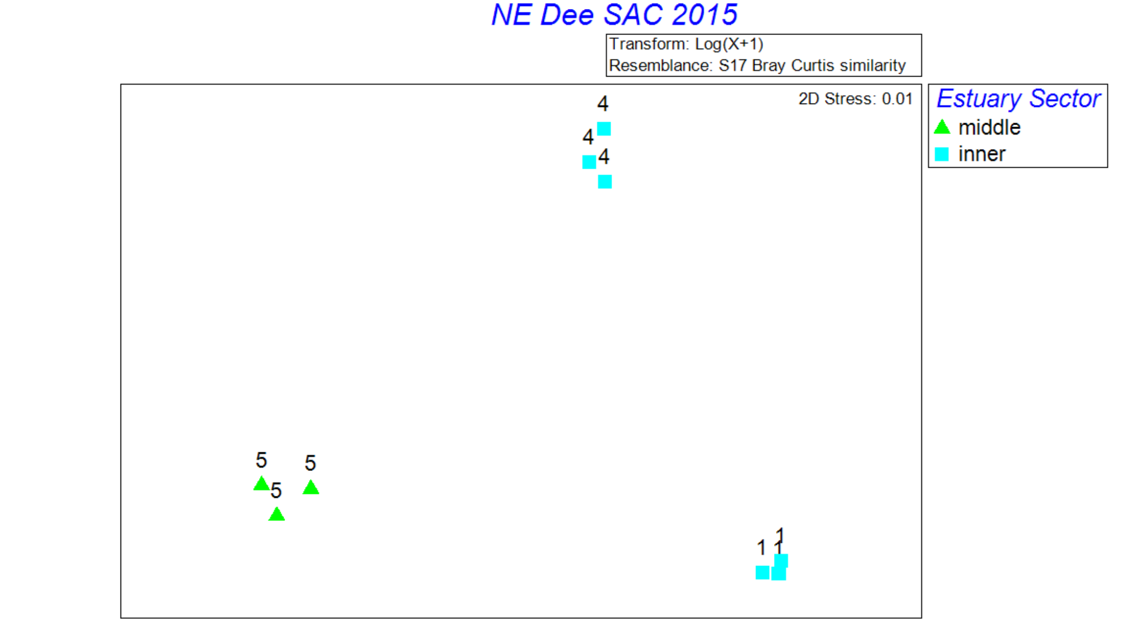
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Peringia ulvae	1.78	8.37	0.99	27.77	27.77
Scolelepis (Scolelepis) squamata	1.16	5.29	0.80	17.53	45.30
Eurydice pulchra	1.40	5.21	0.61	17.26	62.56
Eurydice affinis	1.09	3.13	0.40	10.37	72.92
Ophelia rathkei	0.75	2.38	0.55	7.91	80.83
Pygospio elegans	0.45	1.13	0.37	3.75	84.58
Psammodrilus balanoglossoides	0.54	0.95	0.30	3.16	87.74
NEMATODA	0.55	0.92	0.31	3.04	90.78



Biotope LS.LSa.MuSa.CerPo	Average similarity: 55.33				N=9
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Peringia ulvae	5.10	15.06	3.03	27.23	27.23
Pygospio elegans	4.31	8.65	2.92	15.63	42.86
Cerastoderma edule	2.89	5.88	1.65	10.62	53.48
NEMATODA	2.79	5.62	1.01	10.16	63.64
Corophium volutator	3.19	4.44	0.98	8.03	71.68
Macoma balthica	2.26	3.82	1.40	6.90	78.58
Eteone longa	1.19	1.94	0.95	3.51	82.09
Capitella	1.47	1.82	0.74	3.29	85.38
Cardiidae	1.47	1.61	0.79	2.91	88.29
Mytilus edulis	1.04	1.15	0.79	2.07	90.36



Biotope LS.LSa.MuSa.HedMacEte	Average similarity: 64.68			N=9	
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
NEMATODA	4.80	13.02	4.23	20.14	20.14
Peringia ulvae	4.35	12.16	2.28	18.81	38.95
Pygospio elegans	2.65	8.15	4.39	12.61	51.55
Enchytraeidae	2.96	7.37	2.67	11.40	62.96
Macoma balthica	2.52	5.59	1.21	8.65	71.60
Eteone longa	1.96	4.68	1.32	7.24	78.84
Hediste diversicolor	1.54	4.39	5.68	6.78	85.62
Corophium volutator	2.71	3.44	0.65	5.31	90.94



Biotope LS.LSa.MuSa.BatCare	Average similarity: 87.38	N=3			
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Peringia ulvae	5.42	19.99	12.41	22.88	22.88
NEMATODA	4.67	17.71	54.36	20.27	43.15
Macoma balthica	3.00	11.14	54.36	12.75	55.90
Bathyporeia pilosa	3.02	10.84	96.12	12.40	68.30
Corophium arenarium	1.99	6.91	54.36	7.90	76.21
Pygospio elegans	1.91	6.08	4.51	6.95	83.16
Cerastoderma edule	1.55	4.89	4.26	5.60	88.76
Enchytraeidae	1.44	4.88	4.67	5.58	94.35

Biotope SS.SSa.IMuSa.EcorEns	Average similarity: 55.58	N=3			
Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Donax vittatus	2.99	16.84	6.50	28.60	28.60
Magelona johnstoni	2.30	13.48	5.90	22.89	51.48
Nephtys cirrosa	1.66	8.20	3.30	13.92	65.41
Owenia fusiformis	1.88	7.11	1.49	12.07	77.48
Ophiura ophiura	0.83	4.17	7.12	7.09	84.57
Macoma balthica	0.69	4.17	7.12	7.09	91.66

3.4 Anthropogenic pressures

At transect 12, the collection of *Ensis* spp. was observed by the field surveyors. Based on this single observation, it is not possible to infer whether this is a regular occurrence or a one-off event. No other clear anthropogenic pressures were observed during the survey other than historical sea defence structures likely to predate the designation of the site.

4. Preliminary condition assessment

Qualifying habitats of the Dee Estuary / Aber Dyfrdwy SAC & EMS comprises mudflats and sandflats not covered by seawater at low tide (H1140) (EUNIS code A2). The sedimentary littoral **sub-features**[16] considered in this assessment are:

1. Intertidal mud and sand flats;
2. Intertidal muddy sand communities;
3. Intertidal mud communities: and
4. Intertidal mud and sand supporting habitat (feeding).

A comparison was carried out between historical evidence (Allen and Hemingway 2005, CMACS 2011) and new data obtained in 2015, in an attempt to assess any change in habitat type that may have occurred since these studies were undertaken. It was not possible to derive comparable biotope area from former studies due to different biotope coding (Allen and Hemingway 2005) or incomplete SAC coverage (CMACS 2011). As JNCC habitat codes have changed and been made more complex, it was not possible to ensure an accurate transposition to JNCC 15.03 biotope types (current classification), as such a procedure would likely lead to potential bias and an uncertain assessment as there are no baseline faunal data available to inform the translation of biotope codes. Instead the assessment of the attributes “extent” and “sediment character” was done on available descriptions of life forms previously recorded and general character of the main three estuarine areas focus of this work. Although some of the transects and sample stations in the current survey were in the same location as the previous survey by CMACS in 2011, the survey design (grid-based) was not directly comparable limiting any interpretation to habitat distribution outcomes. Furthermore, only Phase I evidence were available with no quantitative macrofauna data making a meaningful quantitative comparison impossible [17].

[16] Considering mudflats and sandflats not covered by sea water at low tide sub-feature’s attributes as per the work scope. Qualifying feature Estuary (H1130) attributes are not assessed.
[17] Partial baseline provided by 2006 CCW Intertidal Biotope Survey (unpublished dataset) and Allen & Hemmingway (2005).

4.1 Comparison with historical evidence

The outer sector (New Brighton to Hoylake) is still primarily composed of littoral sands with polychaete and amphipod biotopes (LS.LSa.FiSa) ranging from barren sands and impoverished types at upper shore elevations to more diverse communities lower in the shore profile. Muddy fine sands are still present along with patches of muddier sediments and more diverse communities including bivalves and areas of wet rippled sands with *Arenicola marina* casts (LS.LSa.MuSa.MacAre/CerPo.), probably coinciding with less exposed areas. The lower edge of the intertidal continues to be characterised by smooth or rippled medium sand and extensive standing water with more diverse communities such as LS.LSa.MuSa.Lan and SS.SSA.IMuSa.EcorEns (at the edge of the intertidal area). Previously reported clay exposures in this area have not been found.

The middle Dee Estuary sector (Hoylake to Heswall) was consistent with former descriptions of barren, relatively uniform flats (LS.LSa.MoSa.BarS or LS.LSa.FiSa.Po.Ncir) grading through fine and medium sand biotopes (LS.LSa.MoSa.AmSco, LS.LSa.MuSa.BatCare, LS.LSa.MuSa.MacAre) and ending in pioneer (*Spartina*) saltmarsh (LS.LMp.Sm) and/or mixed coarse substrata biotope (LR.FLR.Eph.BLitX). *Arenicola* beds, and mounds, with patches of very abundant *Cerastoderma edule* (LS.LSa.MuSa.CerPo) and patches of areas of *Mytilus edulis* (LS.LBR.LMus.Myt.Mu) are still present. As described before to the south of the area, softer muddy (LS.LMu.MEst. HedMac/HedMacScr) and muddy sands (S.LSa.MuSa.HedMacEte, LS.LSa.MuSa.MacAre) replace sandy biotopes at upper shore elevations and areas fronting pioneering saltmarsh.

The inner sector (Heswall to the Welsh border) contains the same transition from sand and sandy mud biotopes (LS.LSa.MuSa.MacAre; LS.LSa.MuSa.CerPo/BatCare, LS.LSa.MoSa.AmSco.Eur) similar to the middle estuarine sector to significantly muddier biotopes (LS.LMu.MEst.HedMac & LS.LMu.MEst.HedMac/HedMacScr), and areas of pioneering and established saltmarsh (LS.LMp.Sm). This sector maintains the same extensive saltmarsh cover reported previously; potentially showing signs of encroaching into fringing areas of fine sediment (LS.LMu.MEst.HedMac, LS.LSa.MuSa.MacAre).

A spatial assessment of the extent of saltmarsh gain was attempted by comparing the maps produced by IECS in 2005 (Allen and Hemingway 2005) with the extent recorded in the current survey. However, the two surveys mapped different extents of the estuary and it was not possible to make a fair comparison of total area. Nevertheless, it was noted that some new areas of the estuary are now covered by saltmarsh whilst other areas have reverted to muds. These changes may be the result of movements in the main channels and primary/secondary order marsh creeks. It is likely that a net gain in saltmarsh coverage has occurred since 2005 and that this process is continuing along the areas of pioneer marsh noted by the current survey. The lower shore elevations of muddy sand habitats transitioned towards the main channel of the Dee Estuary into sandier more exposed areas similar to the outer estuary (LS.LSa.FiSa.Po.Ncir).

Intertidal mud and sand flats and their communities supporting role was assessed according to known bird feeding dependencies. No quantitative faunal data were available for the analysis and no direct quantitative temporal assessment was possible. Instead the assessment considered presence and abundance of key prey species favoured by intertidal feeders and wading birds:

- Polychaete worms: rag worm *Hediste diversicolor*, lug worm *Arenicola marina*;
- Molluscs: Mud snails *Peringia* spp., mussels *Mytilus edulis*, cockles *Cerastoderma edule*, Baltic tellins *Macoma balthica*; and
- Crustaceans: amphipods e.g. *Corophium* spp., shore crab *Carcinus maenas*, brown shrimp *Crangon crangon*.

4.2 Dee Estuary 2015 Condition Recommendation tables

Table 13. Mudflats and sandflats not covered by sea water at low tide – Sub-features.

SAC Attribute (*Measure*)	Target (subject to natural variation)	Condition Recommendation
Extent *Total area (ha) of intertidal mudflat and sandflat communities within the site measured periodically during the reporting cycle using a combination of remote sensing and ground truthing of boundaries between communities using GPS (frequency to be determined).*	No significant decrease in extent of intertidal mudflats and sandflats from an established baseline. Together the CCW Intertidal Biotope Survey (CCW, 2006; Phase I Intertidal Dataset - unpublished), the English Nature ICES survey (Allen & Hemmingway, 2005) and aerial photographs taken in 1999 by Liverpool Bay Coastal Group provide a baseline.	The extent of muddy sand in the middle and inner estuary and clean sandy shores on moderately exposed areas in the outer estuary have been described by former survey work. Allen and Hemingway (2005) Phase I evidence covers the entire SAC area and the comparative exercise suggests that the general distribution of main habitats (sub-features) and biotope complexes across the outer, middle and inner Dee Estuary EMS have not deviated greatly from those described in section 3.2 (Distribution of biotopes) above. Although sandy mud (LS.LMu.MEst.) and mud (LS.LMu.UEst.) biotope complexes were not mapped in the outer estuary this may be a direct result of the methods used (transect–based combining Phase I and quantitative coring (Phase II) survey rather than a more comprehensive Phase I walkover alone). Small to medium size patches of finer sediment could have been simply missed. This conclusion is supported by the more recent study by CMACS (2011) which reported identical main habitats and comparable biotope complexes to those found in this study. The general distribution of broad habitat was comparable to the evidence forum by the 2015 survey. Although it is not possible to provide conclusive determination of area coverage, it is highly likely that the character and extent of the SAC mudflats and sandflats sub-features have remained within the expected natural variability. Consequently the **CO target for this attribute is judged to have been met**. However, without previous data enabling a robust comparison the confidence on this assessment is medium to low.

Sediment character: *1. Particle size analysis (PSA). Parameters include percentage sand / silt / gravel, mean and median grain size, and sorting coefficient, used to characterise sediment type; measured at a series of locations across the estuary in summer, once during the reporting cycle (sampling locations to be determined).*	Average PSA parameters should not deviate significantly from an established baseline. Baseline to be further established.	No former quantitative sediment PSA data were available for the assessments. Using as proxy the physical information given at the level of biotope complexes (sediment classes), it is highly likely that outer, middle and inner estuarine sectors have all maintained the same general physical character. The sedimentary regime driven by physical processes if likely to maintain a dynamic balance and although changes at the local scale have occurred following cycles or erosion and accretion the steady state of the system is unlikely to have been affected. Due to the lack of precise quantitative baseline, and the inability to make a statistically meaningful comparison, it is not possible to make a specific recommendation of the condition of this attribute. Therefore, the **preliminary assessment for this attribute is unknown**. Note. The results from this survey will form the baseline.
Sediment character: *4. Oxidation - reduction potential (depth of black anoxic layer) measured at a series of locations across the estuary, once during the reporting cycle (sampling locations to be determined).*	Average black layer depth should not deviate significantly from an established baseline. Baseline yet to be established.	Phase I evidence supports the view of a deep redox potential discontinuity (RPD) layer (generally >15 cm), for all sand sediment types including muddy sands indicating well drained sediments and low organic carbon content. Occasional reporting of RPD layer as shallow as 2 cm (more typically 5-7 cm) on muddy sands high on the shore profile suggests site specific conditions and possibly the existence of finer sediment layers on top of more consolidated sands. RPD as shallow as 1 cm was recorded on much softer mud with standing water with abundant *Scrobicularia plana* feeding scars. The depth of the Redox Potential Discontinuity (RPD) layer was in general shallow in the inner estuary at areas of finer sediments high on the shore profile. Lower shore elevations dominated by sandy sediments consistently have deeper RPDs, generally below 10 cm when reported indicating well

		drained sediments and low organic carbon content. The evidence further suggests no anoxic muds are present and the described variability is within normal conditions. Consequently the **CO target for this attribute is judged to have been met**.
Toxic contamination of sediments *Concentrations of List I and List II substances under the Dangerous Substances Directive measured at a series of locations across the estuary (sampling locations and frequency to be determined).*	Comply with Probable Effects Levels (PEL) derived for the interim sediment quality guidelines adopted by Environment Canada (Cole et al., 1999). Baseline to be further established.	All inorganic and organic contaminates measured are inside the Canadian Probable Effects Levels (PEL) thresholds (current CO target). Only metals (mercury, chromium, copper, lead and zinc) exceeded ISQG, most cases in the Heswall sector (inner estuary). No sample was found to exceed the Probable Effect Levels (PEL) for any of the reported analytes. **Consequently the CO target for this attribute is judged to have been met**. A parallel assessment using normalised values following the OSPAR Co-ordinated Environmental Monitoring Programme (CEMP) methods found that most contaminants were below the OSPAR EAC/ERL (concentrations that are unlikely to give rise to unacceptable biological effects) levels. The metals mercury and zinc were above the EAC/ERL thresholds. Three PAHs analytes and the PCB congener 118 exceeded the EAC/ERL. Note. The results from this survey will form the baseline.

Table 14. Mudflats and sandflats not covered by sea water at low tide – Intertidal muddy sand communities.

SAC Attribute (*Measure*)	Target (subject to natural variation)	Condition Recommendation
Distribution *Spatial distribution of **muddy sand biotopes** measured along a series of fixed transects periodically during the reporting cycle using GPS (frequency and transect locations to be determined).*	Spatial distribution of biotopes should not deviate significantly from an established baseline. Baseline to be further established. The CCW Intertidal Biotope Survey (CCW, 2006; Phase I Intertidal Dataset - unpublished), and the English Nature ICES survey (Allen & Hemmingway, 2005) provide a partial baseline.	The distribution of muddy sand biotopes (LS.LSa.MuSa complex) is, as described in Table 13 above, consistent with former evidence for the site. In general the muddy sand shores are comparatively more relevant in the middle and inner estuary sectors, probably reflecting different sedimentary regime. All areas of muddy sand biotopes recorded, LS.LSa.MuSa.MacAre, LS.LSa.MuSa.CerPo, LS.LSa.MuSa.HedMacEte (Phase II only), LS.LSa.MuSa.BatCare, and areas assigned of this biotope complex were comparable to the historical evidence and are generally found at similar locations within the survey transects. Although it is not possible to provide conclusive determinations, it is highly likely that the distribution of all muddy sand biotopes have remained within the expected natural variability. Consequently the **CO target for this attribute is judged to have been met**. However, without previous data from the same transects enabling a precise site-specific comparison the confidence on this assessment is medium. Note. The results from this survey will form the baseline.
Community composition *Number of different **muddy sand biotopes** measured by field visit periodically during the reporting cycle (frequency to be determined)*	No decrease in the variety of biotopes from an established baseline. Baseline to be further established.	Muddy sand biotopes (LS.LSa.MuSa complex) including cockle beds continue to be represented by polychaete and bivalve-dominated communities. The previously reported zonation was clearly observed confirming historical accounts. Communities from upper shore elevations tend to be less diverse in particular across the outer estuary which, given the large difference in total abundance found in the core samples shows a remarkable lower density of organism than middle and inner estuary sectors. The ranked list of species contributing >1% of the total recorded

		abundance included *Peringia ulvae* (Class Gastropoda), nematodes (Phylum Nematoda), *Corophium volutator* (Order Amphipoda), *Pygospio elegans* (Class Polychaeta), *Macoma balthica* (Class Bivalvia), Enchytraeids (Subclass Oligochaeta), *Cerastoderma edule* (Class Bivalvia), *Polydora cornuta* (Class Polychaeta), and nemerteans (Phylum Nemertea). Provided that core samples are likely to underrepresent some large taxa such as *Arenicola marina* and *Ensis* spp. recorded in field notes and that other low density biotope-defining amphipod species such as *Bathyporeia pilosa* and *Corophium arenarium* were also recorded, the assemblage is typical of muddy sandy shores and expected to be comparable to the historical evidence. Although no statistically meaningful comparison with Phase I data is possible due to the lack of precise quantitative baseline, it is likely that the community composition of muddy sand biotopes and number of biotopes have remained within the expected natural variability. However, without previous data enabling a robust comparison it is not possible to make a specific recommendation of the condition of this attribute. Therefore, the **preliminary assessment for this attribute is unknown**. Note. The results from this survey will form the baseline.

Table 15. Mudflats and sandflats not covered by sea water at low tide – Intertidal mud communities.

SAC Attribute (*Measure*)	Target (subject to natural variation)	Condition Recommendation
Distribution *Spatial distribution of **mud biotopes** measured along a series of fixed transects periodically during the reporting cycle using GPS (frequency and transect locations to be determined).*	Spatial distribution of biotopes should not deviate significantly from an established baseline. Baseline to be further established. The CCW Intertidal Biotope Survey (CCW, 2006; Phase I Intertidal Dataset - unpublished), and the English Nature ICES survey (Allen & Hemmingway, 2005) provide a partial baseline.	Sandy mud (LS.LMu.MEst.) and mud (LS.LMu.UEst.) biotopes recorded were greatly limited to areas in the middle and inner estuary. The communities are clearly dominated by a more diverse polychaete/bivalve assemblage (LS.LMu.MEst.HedMacScr) including amphipod species (LS.LMu.UEst.Hed.Cvol). As described before these mud biotopes were not noted in the outer estuary, however, survey methods may have influenced the results. Elsewhere areas assigned to mud biotopes were predominantly upper shore elevations and areas fronting pioneering saltmarsh, results entirely comparable to historical evidence. Although it is not possible to provide conclusive determinations, it is highly likely that the distribution of all mud biotopes have remained within the expected natural variability and areas of mud still exist at localised low energy locations in the outer estuary. **Consequently the CO target for this attribute is judged to have been met**. However, without previous data from the same transects enabling a precise site-specific comparison the confidence on this assessment is medium. Note. The results from this survey will form the baseline.
Community composition *Number of different **mud biotopes** measured on field visits periodically during the*	No decrease in the variety of biotopes from an established baseline. Baseline to be further	Mud Communities tend to occupy upper shore elevations associated with less exposed locations. The ranked list of species contributing >0.5% of the total recorded abundance included *Peringia ulvae* (Class Gastropoda), nematodes (Phylum Nematoda), *Macoma balthica* (Class Bivalvia), *Pygospio elegans* (Class Polychaeta), *Tubificoides benedii* and

reporting cycle (frequency to be determined).	established	Enchytraeids (Subclass Oligochaeta), *Cerastoderma edule* (Class Bivalvia), *Eteone longa* (Class Polychaeta), *Scrobicularia plana* (Class Bivalvia), nemerteans (Phylum Nemertea) *Corophium volutator* (Order Amphipoda) and *Hediste diversicolor* (Class Polychaeta). This assemblage, with the addition of *Mya arenaria* (Class Bivalvia), and *Arenicola marina* (Class Polychaeta) also recorded, is likely to be similar to the communities underpinning the biotopes described by Allen and Hemmingway (2005). Although no statistically meaningful comparison with Phase I data is possible due to the lack of precise quantitative baseline, it is likely that the community composition of mud biotopes have remained within the expected natural variability. However, without previous data enabling a robust comparison it is not possible to make a specific recommendation of the condition of this attribute. Therefore, the **preliminary assessment for this attribute is unknown**. Note. The results from this survey will form the baseline.

Table 16. Mudflats and sandflats not covered by sea water at low tide – Supporting habitat.

SAC Attribute (*Measure*)	Target (subject to natural variation)	Condition Recommendation
Supporting habitat: - food availability within supporting habitat Note: The attributes "extent of intertidal flats" and "spatial distribution of their constituent sediment community types" is captured in the assessment of the sub-features tables above (Tables 13-15) and no additional assessment is required.	Maintain availability of key prey items of preferred prey sizes.	The assessment considered internationally important Annex I Species[18], and additional waterbirds regularly occurring at levels of international importance as migratory birds and wintering assemblage of the Dee Estuary[19]. The provision of feeding resources is the key supporting habitat service provided by intertidal mudflats and sandflats (CO target for the attribute). Intertidal feeders and wading birds prey on molluscs such as mudsnails *Peringia ulvae*, cockles *Cerastoderma edule*, Baltic tellin *Macoma balthica, mussels Mytilus edulis*, peppery furrow shell *Scrobicularia plana* and other bivalves, polychaete worms such as ragworms *Hediste diversicolor*, lugworms *Arenicola marina*, and sand gapers *Mya arenaria,* and crustaceans such as amphipods *Corophium spp. Bathyporeia spp,* brown shrimp *Crangon crangon* and small shore crabs *Carcinus maenas*. All these benthic invertebrate species have been recorded in 2015. By group and excluding nematodes, which despite large numbers contribute little to the total benthic biomass, the greatest contribution is from *Peringia ulvae* a gastropod mollusc (33.6% total recorded catch) closely followed by polychaetes (26 species and 25.7%), amphipods (12 species and 22.6%), bivalve molluscs (11 species and 9.7%) and finally oligochaetes (4 species and 4.5%). The quantitative Phase II data do not provide a comprehensive indication of the available stock or whether it is sufficient to meet the food requirements of the bird populations using the Dee Estuary. Furthermore, no

[18] Bar tailed godwit (*Limosa lapponica*), common tern (*Sterna hirundo*), little tern (*Sterna albifrons*) and sandwich tern (*Sterna sandvicensis*)

[19] Knot (*Calidris canutus islandica*) and little gull (*Hydrocoloeus minutus*); redshank (*Tringa totanus*), shelduck (*Tadorna tadorna*), teal (*Anas crecca*), pintail (*Anas acuta*), oystercatcher (*Haematopus ostralegus*), grey plover (*Pluvialis squatarola*), dunlin (*Calidris alpina alpina*) (Ramsar), black tailed godwit (*Limosa limosa islandica*), and curlew (*Numenius arquata*)

		statistically meaningful comparison with historical data is possible due to the lack of precise quantitative baseline. Given the lack of evidence of significant changes in the distribution of mudflats and sandflats biotopes and the variety of prey items recorded in 2015 it is likely that food availability within these supporting habitats have remained within the expected natural variability. However, without a precise determination of the available invertebrate stock across preferred prey types (species and size range), and similar baseline data enabling a robust comparison it is not possible to make a specific recommendation of the condition of this attribute. Therefore, the **preliminary assessment for this attribute is unknown**.

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6. Appendices

6.1 Appendix I. Photograph log.

Date	Image_name	Sector	Name	Transect	Date	Image_name	Sector	Name	Transect	Date	Image_name	Sector	Name	Transect
30/08/2015	IMG_0175.JPG	Middle	West Kirby	5	31/08/2015	IMG_0020.JPG	Outer	New Brighton	13	02/09/2015	GEDC0008.JPG	Middle	West Kirby	9
30/08/2015	IMG_0176.JPG	Middle	West Kirby	5	31/08/2015	IMG_0021.JPG	Outer	New Brighton	13	02/09/2015	GEDC0009.JPG	Middle	West Kirby	9
30/08/2015	IMG_0177.JPG	Middle	West Kirby	5	31/08/2015	IMG_0022.JPG	Outer	New Brighton	13	02/09/2015	GEDC0010.JPG	Middle	West Kirby	9
30/08/2015	IMG_0178.JPG	Middle	West Kirby	5	31/08/2015	IMG_0023.JPG	Outer	New Brighton	13	02/09/2015	GEDC0011.JPG	Middle	West Kirby	9
30/08/2015	IMG_0179.JPG	Middle	West Kirby	5	31/08/2015	IMG_0024.JPG	Outer	New Brighton	13	02/09/2015	GEDC0012.JPG	Middle	West Kirby	9
30/08/2015	IMG_0180.JPG	Middle	West Kirby	5	31/08/2015	IMG_0025.JPG	Outer	New Brighton	13	02/09/2015	GEDC0013.JPG	Middle	West Kirby	9
30/08/2015	IMG_0181.JPG	Middle	West Kirby	5	31/08/2015	IMG_0026.JPG	Outer	New Brighton	13	02/09/2015	GEDC0014.JPG	Middle	West Kirby	9
30/08/2015	IMG_0182.JPG	Middle	West Kirby	5	31/08/2015	IMG_0027.JPG	Outer	New Brighton	13	02/09/2015	GEDC0015.JPG	Middle	West Kirby	9
30/08/2015	IMG_0183.JPG	Middle	West Kirby	5	31/08/2015	IMG_0028.JPG	Outer	New Brighton	13	16/09/2015	APDC0073.JPG	Inner	Heswall	2
30/08/2015	IMG_0184.JPG	Middle	West Kirby	5	31/08/2015	IMG_0029.JPG	Outer	New Brighton	13	16/09/2015	APDC0074.JPG	Inner	Heswall	2
30/08/2015	IMG_0185.JPG	Middle	West Kirby	5	01/09/2015	APDC0061.JPG	Outer	New Brighton	12	16/09/2015	APDC0075.JPG	Inner	Heswall	2
30/08/2015	IMG_0186.JPG	Middle	West Kirby	6	01/09/2015	APDC0062.JPG	Outer	New Brighton	12	16/09/2015	APDC0076.JPG	Inner	Heswall	2
30/08/2015	IMG_0187.JPG	Middle	West Kirby	6	01/09/2015	APDC0063.JPG	Outer	New Brighton	12	16/09/2015	APDC0077.JPG	Inner	Heswall	1
30/08/2015	IMG_0188.JPG	Middle	West Kirby	6	01/09/2015	APDC0064.JPG	Outer	New Brighton	12	16/09/2015	APDC0078.JPG	Inner	Heswall	1
30/08/2015	IMG_0189.JPG	Middle	West Kirby	6	01/09/2015	APDC0065.JPG	Outer	New Brighton	12	16/09/2015	APDC0079.JPG	Inner	Heswall	1
31/08/2015	APDC0061.JPG	Outer	New Brighton	14	01/09/2015	APDC0066.JPG	Outer	New Brighton	12	17/09/2015	APDC0080.JPG	Inner	Heswall	0
31/08/2015	APDC0062.JPG	Outer	New Brighton	14	01/09/2015	APDC0067.JPG	Outer	New Brighton	10	17/09/2015	APDC0081.JPG	Inner	Heswall	0
31/08/2015	APDC0063.JPG	Outer	New Brighton	14	01/09/2015	APDC0068.JPG	Outer	New Brighton	10	17/09/2015	APDC0082.JPG	Inner	Heswall	0
31/08/2015	APDC0064.JPG	Outer	New Brighton	14	01/09/2015	APDC0069.JPG	Outer	New Brighton	10	17/09/2015	APDC0083.JPG	Inner	Heswall	0
31/08/2015	APDC0065.JPG	Outer	New Brighton	14	01/09/2015	GEDC0003.JPG	Outer	New Brighton	11	17/09/2015	APDC0084.JPG	Inner	Heswall	0
31/08/2015	IMG_0013.JPG	Outer	New Brighton	13	01/09/2015	GEDC0004.JPG	Outer	New Brighton	11	18/09/2015	IMG_0100.JPG	Middle	West Kirby	8
31/08/2015	IMG_0014.JPG	Outer	New Brighton	13	01/09/2015	GEDC0005.JPG	Outer	New Brighton	11	18/09/2015	IMG_0101.JPG	Middle	West Kirby	8
31/08/2015	IMG_0015.JPG	Outer	New Brighton	13	02/09/2015	APDC0070.JPG	Middle	West Kirby	8	18/09/2015	IMG_0102.JPG	Middle	West Kirby	8
31/08/2015	IMG_0016.JPG	Outer	New Brighton	13	02/09/2015	APDC0071.JPG	Middle	West Kirby	8	18/09/2015	IMG_0103.JPG	Middle	West Kirby	8
31/08/2015	IMG_0017.JPG	Outer	New Brighton	13	02/09/2015	APDC0072.JPG	Middle	West Kirby	8	18/09/2015	IMG_0104.JPG	Middle	West Kirby	8
31/08/2015	IMG_0018.JPG	Outer	New Brighton	13	02/09/2015	GEDC0006.JPG	Middle	West Kirby	9	18/09/2015	IMG_0105.JPG	Middle	West Kirby	8
31/08/2015	IMG_0019.JPG	Outer	New Brighton	13	02/09/2015	GEDC0007.JPG	Middle	West Kirby	9					

6.2 Appendix II. Raw macrofauna data.

Latin name	taxon details (Sample Labels)	WKC1a	WKC1b	WKC1c	WKC2a	WKC2b	WKC2c	WKC3a	WKC3b	WKC3c	WKC4a	WKC4b	WKC4c	WKC5a	WKC5b	WKC5c	WKC6a	WKC6b	WKC6c	WKC7a	WKC7b	WKC7c	WKC8a	WKC8b	WKC8c	WKC9a	WKC9b	WKC9c
COLLEMBOLA	Collembola (Class)		9	63																								
Dolichopodidae	Diptera (Order)	2	4	7																								
Clytia gracilis	Hydrozoa (Class)																											
NEMERTEA	Nemertea (Phylum)	1	1	3	8	11	19	48	50	38						1								3				
NEMATODA	Nematoda (Phylum)	21	12	27	81	108	103	66	63	39	2	5	1	2	1		47	50	30	28				565				
Baltidrilus costatus	Oligochaeta (Subclass)			2																								
Tubificoides benedii	Oligochaeta (Subclass)	11	5	16	43	16	65	2	4	7				2	1													
Tubificoides pseudogaster	Oligochaeta (Subclass)	3																										
Enchytraeidae	Oligochaeta (Subclass)	23	3	2	7	52	19		3	2																		
Ophelia rathkei	Polychaeta (Class)																3	6	4									
Owenia fusiformis	Polychaeta (Class)																			1								
Eteone longa	Polychaeta (Class)	13	14	32	11	17	9	5	14	4						1	1	4	4							1		
Lanice conchilega	Polychaeta (Class)																											
Manayunkia aestuarina	Polychaeta (Class)																											
Glycera tridactyla	Polychaeta (Class)																											
Microphthalmus sczelkowii	Polychaeta (Class)							6																				
Syllis variegata	Polychaeta (Class)																											
Hediste diversicolor	Polychaeta (Class)	2	2	3	3	1	1			1								4	1									
Alitta succinea	Polychaeta (Class)								1	3																		
Nephtys	Polychaeta (Class)										1	1		5	5												1	3
Nephtys cirrosa	Polychaeta (Class)										1	3	2							1	2			1	2	2	1	1
Nephtys hombergii	Polychaeta (Class)									1				4	1	1												
Scoloplos (Scoloplos) armiger	Polychaeta (Class)																											
Polydora cornuta	Polychaeta (Class)							27	114	66																		
Pygospio elegans	Polychaeta (Class)	41	12	19	33	23	29	378	644	950				299	42	91	6	6	4							1		
Scolelepis mesnili	Polychaeta (Class)																							1				
Scolelepis (Scolelepis) squamata	Polychaeta (Class)																							1				
Spio martinensis	Polychaeta (Class)													2						4	1	1				7	1	3
Spiophanes bombyx	Polychaeta (Class)																											
Streblospio shrubsolii	Polychaeta (Class)								1							1												
Tharyx	Polychaeta (Class)							1	2	3				15	8													
Psammodrilus balanoglossoides	Polychaeta (Class)																											
Capitella	Polychaeta (Class)							13	25	19							1	4	7			1						
Ophelia borealis	Polychaeta (Class)																											
Chaetozone christiei	Polychaeta (Class)																											
Magelona johnstoni	Polychaeta (Class)																											
Cumopsis goodsir	Cumacea (Order)																											
DECAPODA	Decapoda (Order)					1			1	1						2												
Crangon crangon	Decapoda (Order)																											
Carcinus maenas	Decapoda (Order)					1	1			2				3														
Portumnus latipes	Decapoda (Order)																									1		
Perioculodes longimanus	Amphipoda (Order)																											
Pontocrates altamarinus	Amphipoda (Order)																											
Nototropis swammerdamei	Amphipoda (Order)																											
Bathyporeia	Amphipoda (Order)																							2				1
Bathyporeia elegans	Amphipoda (Order)																											
Bathyporeia guilliamsoniana	Amphipoda (Order)																											
Bathyporeia nana	Amphipoda (Order)																											
Bathyporeia pilosa	Amphipoda (Order)																											
Bathyporeia sarsi	Amphipoda (Order)																					1	5	3	2	3		
Haustorius arenarius	Amphipoda (Order)																						1	1				
Megaluropus agilis	Amphipoda (Order)																											
Corophium	Amphipoda (Order)																1											
Corophium arenarium	Amphipoda (Order)																											
Corophium volutator	Amphipoda (Order)	1	2	1	2	2	11	256	148	360		2	2	1	60	291	1		1									
Eurydice affinis	Isopoda (Order)																									1		
Eurydice pulchra	Isopoda (Order)																							1				
Acteon tornatilis	Gastropoda (Class)																											
Retusa obtusa	Gastropoda (Class)																											
Peringia ulvae	Gastropoda (Class)	57	54	52	231	370	201	128	120	138			1	287	174	356	228	173	52									
Mytilus edulis	Bivalvia (Class)							6	4	10				4	2	1												
Cardiidae	Bivalvia (Class)						7		48	38				7	3	2	2											
Cerastoderma edule	Bivalvia (Class)				13	64	10	75	49	102		3		25	13	8	14	9										
Cerastoderma edule	Bivalvia (Class)									7																		
Ensis siliqua	Bivalvia (Class)					1			1					1		1												
TELLINOIDEA	Bivalvia (Class)	2			17	16	9	9	3	5						2						1			1			
Tellina tenuis	Bivalvia (Class)																				2					1		
Tellina fabula	Bivalvia (Class)													1														
Macoma balthica	Bivalvia (Class)			1	34	39	31	14	33	38				11	11	9		2	1									
Donax vittatus	Bivalvia (Class)																											
Scrobicularia plana	Bivalvia (Class)	1	1	1	10	8	8	1	1	1						1												
Mya arenaria	Bivalvia (Class)									1																		
Mya arenaria	Bivalvia (Class)				1			25	36	32				1														
Thracia phaseolina	Bivalvia (Class)																											
Amphiuridae	Ophiuroidea (Class)																											
Amphiura	Ophiuroidea (Class)																											
Ophiura ophiura	Ophiuroidea (Class)																											
Echinocardium cordatum	Echinoidea (Class)																											

Latin name	taxon details (Sample Labels)	NBC1a	NBC1b	NBC1c	NBC2a	NBC2b	NBC2c	NBC3a	NBC3b	NBC3c	NBC4a	NBC4b	NBC4c	NBC5a	NBC5b	NBC5c	NBC6a	NBC6b	NBC6c	NBC7a	NBC7b	NBC7c
COLLEMBOLA	Collembola (Class)																					
Dolichopodidae	Diptera (Order)																					
Clytia gracilis	Hydrozoa (Class)											P										
NEMERTEA	Nemertea (Phylum)		2									1					2				3	
NEMATODA	Nematoda (Phylum)							2				2	4	1			10	11	4			
Baltidrilus costatus	Oligochaeta (Subclass)																					
Tubificoides benedii	Oligochaeta (Subclass)																					
Tubificoides pseudogaster	Oligochaeta (Subclass)																					
Enchytraeidae	Oligochaeta (Subclass)										1											
Ophelia rathkei	Polychaeta (Class)	1	1											4	2	2	5	11	5			
Owenia fusiformis	Polychaeta (Class)					1					1	9	13									
Eteone longa	Polychaeta (Class)	1		1			1				1	1										
Lanice conchilega	Polychaeta (Class)											1										
Manayunkia aestuarina	Polychaeta (Class)																					
Glycera tridactyla	Polychaeta (Class)												1									
Microphthalmus sczelkowii	Polychaeta (Class)																					
Syllis variegata	Polychaeta (Class)																					
Hediste diversicolor	Polychaeta (Class)																					
Alitta succinea	Polychaeta (Class)																					
Nephtys	Polychaeta (Class)				5	3	1				6	4	2									
Nephtys cirrosa	Polychaeta (Class)					1	1	2	2	1		2										
Nephtys hombergii	Polychaeta (Class)																					
Scoloplos (Scoloplos) armiger	Polychaeta (Class)																					
Polydora cornuta	Polychaeta (Class)																					
Pygospio elegans	Polychaeta (Class)		1		1									1	4	4	2	2				
Scolelepis mesnili	Polychaeta (Class)							5	8	4												
Scolelepis (Scolelepis) squamata	Polychaeta (Class)	5	1	1										1	3	3	1		3	21	12	19
Spio martinensis	Polychaeta (Class)				1		1	1	6	6												
Spiophanes bombyx	Polychaeta (Class)							1														
Streblospio shrubsolii	Polychaeta (Class)																					
Tharyx	Polychaeta (Class)																					
Psammodrilus balanoglossoides	Polychaeta (Class)													1	4		3	9	7			
Capitella	Polychaeta (Class)									1				3								
Ophelia borealis	Polychaeta (Class)						1					1										
Chaetozone christiei	Polychaeta (Class)												1									
Magelona johnstoni	Polychaeta (Class)		1			3					9	8	10									
Cumopsis goodsir	Cumacea (Order)								1									1				
DECAPODA	Decapoda (Order)																					
Crangon crangon	Decapoda (Order)																		1			
Carcinus maenas	Decapoda (Order)																					
Portumnus latipes	Decapoda (Order)							1														
Perioculodes longimanus	Amphipoda (Order)										1		1									
Pontocrates altamarinus	Amphipoda (Order)										1											
Nototropis swammerdamei	Amphipoda (Order)											1										
Bathyporeia	Amphipoda (Order)				3		2					2										
Bathyporeia elegans	Amphipoda (Order)				1		1															
Bathyporeia guilliamsoniana	Amphipoda (Order)											1										
Bathyporeia nana	Amphipoda (Order)						1															
Bathyporeia pilosa	Amphipoda (Order)		1	1																1		
Bathyporeia sarsi	Amphipoda (Order)	2	3	7																		
Haustorius arenarius	Amphipoda (Order)			1																1	1	
Megaluropus agilis	Amphipoda (Order)											1										
Corophium	Amphipoda (Order)																					
Corophium arenarium	Amphipoda (Order)																		1			
Corophium volutator	Amphipoda (Order)		1										1									
Eurydice affinis	Isopoda (Order)	13	30	8																24	7	16
Eurydice pulchra	Isopoda (Order)	30	36	20												1	2	5		9	13	10
Acteon tornatilis	Gastropoda (Class)										1											
Retusa obtusa	Gastropoda (Class)																1	2				
Peringia ulvae	Gastropoda (Class)		1	2				1	2			19		27	11	20	55	32	104	1	1	1
Mytilus edulis	Bivalvia (Class)		1							1		2										
Cardiidae	Bivalvia (Class)																					
Cerastoderma edule	Bivalvia (Class)								1													
Cerastoderma edule	Bivalvia (Class)																					
Ensis siliqua	Bivalvia (Class)																					
TELLINOIDEA	Bivalvia (Class)																					
Tellina tenuis	Bivalvia (Class)						1															
Tellina fabula	Bivalvia (Class)																					
Macoma balthica	Bivalvia (Class)										1	1	1			1			1			
Donax vittatus	Bivalvia (Class)										28	15	16									
Scrobicularia plana	Bivalvia (Class)																					
Mya arenaria	Bivalvia (Class)					1																
Mya arenaria	Bivalvia (Class)				2																	
Thracia phaseolina	Bivalvia (Class)										1											
Amphiuridae	Ophiuroidea (Class)												1									
Amphiura	Ophiuroidea (Class)											1										
Ophiura ophiura	Ophiuroidea (Class)					1					1	1										
Echinocardium cordatum	Echinoidea (Class)					1																

Latin name	taxon details (Sample Labels)	HWC1a	HWC1b	HWC1c	HWC2a	HWC2b	HWC2c	HWC3a	HWC3b	HWC3c	HWC4a	HWC4b	HWC4c	MSC_Code	Qualifier	Notes Sample	Notes Truncation
COLLEMBOLA	Collembola (Class)								2	3				na			No
Dolichopodidae	Diptera (Order)										2			na	Larvae		y; non marine
Clytia gracilis	Hydrozoa (Class)													D502			N; presence
NEMERTEA	Nemertea (Phylum)				1	2	2				3	5	9	G1			No
NEMATODA	Nematoda (Phylum)	539	820	943	122	98	98	21	27	20	97	119	151	HD1			No
Baltidrilus costatus	Oligochaeta (Subclass)													P1479			No
Tubificoides benedii	Oligochaeta (Subclass)										2	3		P1490			No
Tubificoides pseudogaster	Oligochaeta (Subclass)													P1498	sp. agg.		No
Enchytraeidae	Oligochaeta (Subclass)	48	91	126	4	2	4	1	32	2	14	11	11	P1501			No
Ophelia rathkei	Polychaeta (Class)													P1003			No
Owenia fusiformis	Polychaeta (Class)													P1098			No
Eteone longa	Polychaeta (Class)		1	6	3		3	1	1	2	8	12	3	P118	sp. agg.		No
Lanice conchilega	Polychaeta (Class)													P1195			No
Manayunkia aestuarina	Polychaeta (Class)								1					P1294			No
Glycera tridactyla	Polychaeta (Class)													P265			No
Microphthalmus sczelkowii	Polychaeta (Class)													P332			No
Syllis variegata	Polychaeta (Class)	1												P371			No
Hediste diversicolor	Polychaeta (Class)	11	4	6				3		2	3	2	5	P462			No
Alitta succinea	Polychaeta (Class)													P471			No
Nephtys	Polychaeta (Class)													P494	juv./sp. indet.		Y; split in genus
Nephtys cirrosa	Polychaeta (Class)													P498			Y; split in genus
Nephtys hombergii	Polychaeta (Class)													P499			Y; split in genus
Scoloplos (Scoloplos) armiger	Polychaeta (Class)											1		P672			No
Polydora cornuta	Polychaeta (Class)													P753			No
Pygospio elegans	Polychaeta (Class)	11	17	5	6	10	3	17	21	41	10	8	16	P776			No
Scolelepis mesnili	Polychaeta (Class)													P782			No
Scolelepis (Scolelepis) squamata	Polychaeta (Class)													P783			No
Spio martinensis	Polychaeta (Class)													P791			No
Spiophanes bombyx	Polychaeta (Class)													P794			No
Streblospio shrubsolii	Polychaeta (Class)							4						P799			No
Tharyx	Polychaeta (Class)													P845	A		No
Psammodrilus balanoglossoides	Polychaeta (Class)													P864			No
Capitella	Polychaeta (Class)		1				2				4	5	4	P906	sp. agg.		No
Ophelia borealis	Polychaeta (Class)													P999			No
Chaetozone christiei	Polychaeta (Class)													na			No
Magelona johnstoni	Polychaeta (Class)													na			No
Cumopsis goodsir	Cumacea (Order)													S1188			No
DECAPODA	Decapoda (Order)													S1276	megalopa		Y; split in Order Decapoda
Crangon crangon	Decapoda (Order)													S1385			Y; split in Order Decapoda
Carcinus maenas	Decapoda (Order)							1	1					S1594	juv.		Y; split in Order Decapoda
Portumnus latipes	Decapoda (Order)													S1596	juv.		Y; split in Order Decapoda
Perioculodes longimanus	Amphipoda (Order)													S131			No
Pontocrates altamarinus	Amphipoda (Order)													S133			No
Nototropis swammerdamei	Amphipoda (Order)													S412			No
Bathyporeia	Amphipoda (Order)													S451	juv./sp. indet.		Y; split in genus
Bathyporeia elegans	Amphipoda (Order)													S452			Y; split in genus
Bathyporeia guilliamsoniana	Amphipoda (Order)													S454			Y; split in genus
Bathyporeia nana	Amphipoda (Order)													S455			Y; split in genus
Bathyporeia pilosa	Amphipoda (Order)				17	15	29							S457			Y; split in genus
Bathyporeia sarsi	Amphipoda (Order)					1								S458			Y; split in genus
Haustorius arenarius	Amphipoda (Order)													S462			No
Megaluropus agilis	Amphipoda (Order)													S489			No
Corophium	Amphipoda (Order)					1						2		S605	sp. indet.		Y; split in genus
Corophium arenarium	Amphipoda (Order)				10	4	5				18	16	20	S609			Y; split in genus
Corophium volutator	Amphipoda (Order)	524	548	784	3				1			13		S616			Y; split in genus
Eurydice affinis	Isopoda (Order)													S851			No
Eurydice pulchra	Isopoda (Order)		1											S854			No
Acteon tornatilis	Gastropoda (Class)													W1006			No
Retusa obtusa	Gastropoda (Class)													W1077			No
Peringia ulvae	Gastropoda (Class)	205	205	259	141	284	282	110	23	57	181	150	1	W385			No
Mytilus edulis	Bivalvia (Class)													W1695	juv.		No
Cardiidae	Bivalvia (Class)			1										W1938	sp. indet.	Shells eroded	No
Cerastoderma edule	Bivalvia (Class)				2	5	3					2		W1961			Y; adult+juv
Cerastoderma edule	Bivalvia (Class)		1			1	1							W1961	juv.		Y; adult+juv
Ensis siliqua	Bivalvia (Class)													W2001	juv.		No
TELLINOIDEA	Bivalvia (Class)	7	18	22			7			1	8	12	10	W2007	juv./sp. indet.		Y; split in fam. Tellinidae
Tellina tenuis	Bivalvia (Class)													W2012			Y; split in fam. Tellinidae
Tellina fabula	Bivalvia (Class)													W2019			Y; split in fam. Tellinidae
Macoma balthica	Bivalvia (Class)	30	17	35	7	13	11	4	1	2	35	44	22	W2029			Y; split in fam. Tellinidae
Donax vittatus	Bivalvia (Class)													W2041			No
Scrobicularia plana	Bivalvia (Class)							5	5	3	1	1	1	W2068			No
Mya arenaria	Bivalvia (Class)													W2149			Y; adult+juv
Mya arenaria	Bivalvia (Class)		2											W2149	juv.		Y; adult+juv
Thracia phaseolina	Bivalvia (Class)													W2231			No
Amphiuridae	Ophiuroidea (Class)													ZB148	juv.		Y; Ophiura ophiura
Amphiura	Ophiuroidea (Class)													ZB149	juv.		Y; Ophiura ophiura
Ophiura ophiura	Ophiuroidea (Class)													ZB170			Y; Ophiura ophiura
Echinocardium cordatum	Echinoidea (Class)													ZB223			No

6.3 Appendix III. Raw particle size distribution data.

φ interval	Grain Size Fraction (microns)	WKC1	WKC2	WKC3	WKC4	WKC5	WKC6	WKC7	WKC8	WKC9	NBC1	NBC2	NBC3	NBC4	NBC5	NBC6	NBC7	HWC1	HWC2	HWC3	HWC4
>10	< 0.98 microns	1.1700	2.5900	0.6440	-	0.9590	-	-	-	-	-	-	-	-	-	-	-	-	-	3.0200	0.6690
10 to 9.5	0.98 to 1.38	0.9500	1.8200	0.5450	-	0.7590	-	-	-	-	-	-	-	-	-	-	-	-	-	2.0800	0.5590
9.5 to 9	1.38 to 1.95	1.3400	2.5500	0.8120	-	1.1100	-	-	-	-	-	-	-	-	-	-	-	0.0999	0.2000	2.8100	0.8180
9 to 8.5	1.95 to 2.76	2.2900	4.1300	1.4500	-	1.9000	-	-	-	-	-	-	-	-	-	-	-	0.3300	0.4190	4.5400	1.4300
8.5 to 8	2.76 to 3.91	3.7500	6.3000	2.4500	-	3.0600	-	-	-	-	-	-	-	-	-	-	-	0.5700	0.7380	6.8800	2.3900
8 to 7.5	3.91 to 5.52	4.3600	6.7300	3.0000	-	3.4400	-	-	-	-	-	-	-	-	-	-	-	0.6900	0.8780	7.3300	2.9000
7.5 to 7	5.52 to 7.81	4.5800	6.5100	3.3700	-	3.4400	-	-	-	-	-	-	-	-	-	-	-	0.8000	0.9380	7.2200	3.1700
7 to 6.5	7.81 to 11.1	4.0900	5.2200	3.2100	-	2.8800	-	-	-	-	-	-	-	-	-	-	-	0.8700	0.8780	6.2100	2.9000
6.5 to 6	11.1 to 15.6	3.2600	3.4600	2.5100	-	2.2500	-	-	-	-	-	-	-	-	-	-	-	0.7600	0.7480	4.8500	2.2900
6 to 5.5	15.6 to 22.1	2.9900	2.5800	2.0100	-	2.3800	-	-	-	-	-	-	-	-	-	-	-	0.4100	0.6090	4.4900	2.1300
5.5 to 5	22.1 to 31.3	2.6400	2.0800	1.7700	-	2.3300	-	-	-	-	-	-	-	-	-	-	-	0.0100	0.2090	4.9000	1.9100
5 to 4.5	31.3 to 44.2	2.2900	1.8000	1.5900	-	0.9890	-	-	-	-	-	-	-	-	-	-	-	-	-	6.5700	0.8880
4.5 to 4	44.2 to 62.5	4.3500	3.0300	0.9710	-	0.2300	-	-	-	-	-	-	-	-	-	-	-	0.1100	0.0499	9.5800	0.1100
4 to 3.5	62.5 to 88.4	11.0000	7.3600	0.1390	-	4.7500	-	0.0398	0.0200	0.0100	0.0198	0.0200	0.0600	0.0593	-	-	-	5.1800	3.1200	11.9000	3.1700
3.5 to 3	88.4 to 125	19.1000	13.5000	0.6640	0.0700	19.4000	0.7010	4.1100	3.3300	2.7800	3.2900	3.1100	5.3900	4.6400	0.1500	0.6090	0.3100	23.9000	17.6000	10.8000	14.7000
3 to 2.5	125 to 177	19.7000	15.9000	9.4500	6.4000	29.6000	13.5000	25.2000	25.8000	23.9000	23.1000	22.8000	31.9000	24.0000	8.6500	12.4000	11.3000	37.0000	33.6000	5.7400	26.9000
2.5 to 2	177 to 250	10.7000	10.9000	25.8000	30.9000	18.2000	37.4000	40.7000	43.5000	43.4000	39.8000	40.5000	43.2000	37.5000	34.2000	35.6000	38.9000	23.8000	28.8000	1.0600	23.5000
2 to 1.5	250 to 354	1.4500	3.3400	28.1000	43.2000	2.2500	36.4000	25.6000	24.7000	27.1000	27.2000	28.0000	18.2000	26.2000	41.1000	37.1000	39.1000	5.4000	10.7000	-	9.3100
1.5 to 1	354 to 500	-	-	10.3000	18.8000	-	10.5000	3.9300	2.6400	2.7600	5.4100	5.2400	1.1100	6.1400	15.0000	13.1000	10.1000	0.0800	0.2390	-	0.0100
1 to 0.5	500 to 707	-	-	0.2380	0.7300	-	0.1970	-	0.0100	-	0.1390	0.0399	-	0.2170	0.8700	0.9880	0.2500	-	-	-	-
0.5 to 0	707 to 1000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0 to -0.5	1,000 to 1,400	-	0.0131	0.0363	-	0.0054	0.0759	0.1040	-	-	0.0864	0.0515	0.0102	0.0800	-	0.0473	-	0.0088	0.0078	-	0.0170
-0.5 to -1.0	1,400 to 2,000	-	0.0222	0.0363	-	0.0150	0.1040	0.1030	-	-	0.0978	0.0492	0.0096	0.0853	-	0.0329	-	0.0054	0.0109	-	0.0248
-1.0 to -1.5	2,000 to 2,800	-	0.0074	0.0575	-	0.0075	0.0951	0.1050	-	-	0.1060	0.0334	0.0127	0.1260	-	0.0209	-	0.0025	0.0133	-	0.0202
-1.5 to -2.0	2,800 to 4,000	-	0.0082	0.0514	-	0.0118	0.1370	0.0524	-	-	0.1150	0.0170	0.0078	0.1010	-	0.0341	-	0.0044	0.0289	-	0.0091
-2.0 to -2.5	4,000 to 5,600	-	-	0.1450	-	-	0.1260	0.0518	-	-	0.1490	0.0119	0.0205	0.1770	-	0.0275	-	0.0005	0.0187	-	0.0293
-2.5 to -3.0	5,600 to 8,000	-	-	0.0741	-	0.0075	0.1110	0.0325	-	-	0.2140	-	0.0139	0.1510	-	0.0090	-	0.0098	0.0944	-	0.0319
-3.0 to -3.5	8,000 to 11,200	-	0.0246	0.0544	-	0.0226	0.1010	0.0259	-	-	0.1160	0.0175	0.0145	0.2450	-	0.0724	-	0.0196	0.0811	-	0.0202
-3.5 to -4.0	11,200 to 16,000	-	-	0.3780	-	-	0.4600	-	-	-	0.1700	-	-	0.2290	-	-	-	-	-	-	-
-4.0 to -4.5	16,000 to 22,400	-	0.1080	0.1240	-	-	0.0863	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0704
< -5.0	> 22,400	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Analyst Comment		muddy sand	slightly gravelly muddy sand	slightly gravelly muddy sand	sand	slightly gravelly muddy sand	slightly gravelly sand	slightly gravelly sand	sand	sand	slightly gravelly sand	slightly gravelly sand	slightly gravelly sand	slightly gravelly sand	sand	slightly gravelly sand	sand	slightly gravelly sand	slightly gravelly sand	sandy mud	slightly gravelly muddy sand
Sorting Coefficient		2.150	2.500	2.260	0.462	2.070	0.484	0.483	0.462	0.459	0.507	0.486	0.450	0.534	0.463	0.488	0.454	0.593	0.928	2.220	2.000
Particle Diameter: Median (mm)		0.090	0.066	0.218	0.277	0.125	0.246	0.211	0.209	0.213	0.217	0.217	0.196	0.215	0.265	0.253	0.249	0.146	0.160	0.023	0.142
Grain Size Inclusive Mean (mm)		0.046	0.035	0.095	0.274	0.061	0.247	0.211	0.209	0.213	0.218	0.217	0.194	0.216	0.261	0.252	0.249	0.145	0.157	0.019	0.075
Particle Diameter: Mean (mm)		0.092	0.107	0.300	0.291	0.121	0.369	0.238	0.221	0.225	0.294	0.237	0.210	0.310	0.280	0.281	0.263	0.156	0.184	0.044	0.160
Kurtosis		0.809	0.652	2.120	0.965	1.210	1.010	0.885	0.930	0.927	0.957	0.918	0.938	0.939	0.993	1.000	0.996	1.070	2.110	0.720	2.150
Grain Size Inclusive Kurtosis (mm)		0.571	0.636	0.231	0.512	0.433	0.495	0.541	0.525	0.526	0.515	0.529	0.522	0.522	0.502	0.500	0.501	0.478	0.231	0.607	0.226
Inclusive Graphic Skewness :- {SKI}		-0.610	-0.501	-0.726	-0.030	-0.713	0.019	0.000	0.000	-0.013	0.034	-0.002	0.002	0.046	-0.044	-0.010	-0.004	-0.103	-0.307	-0.192	-0.670

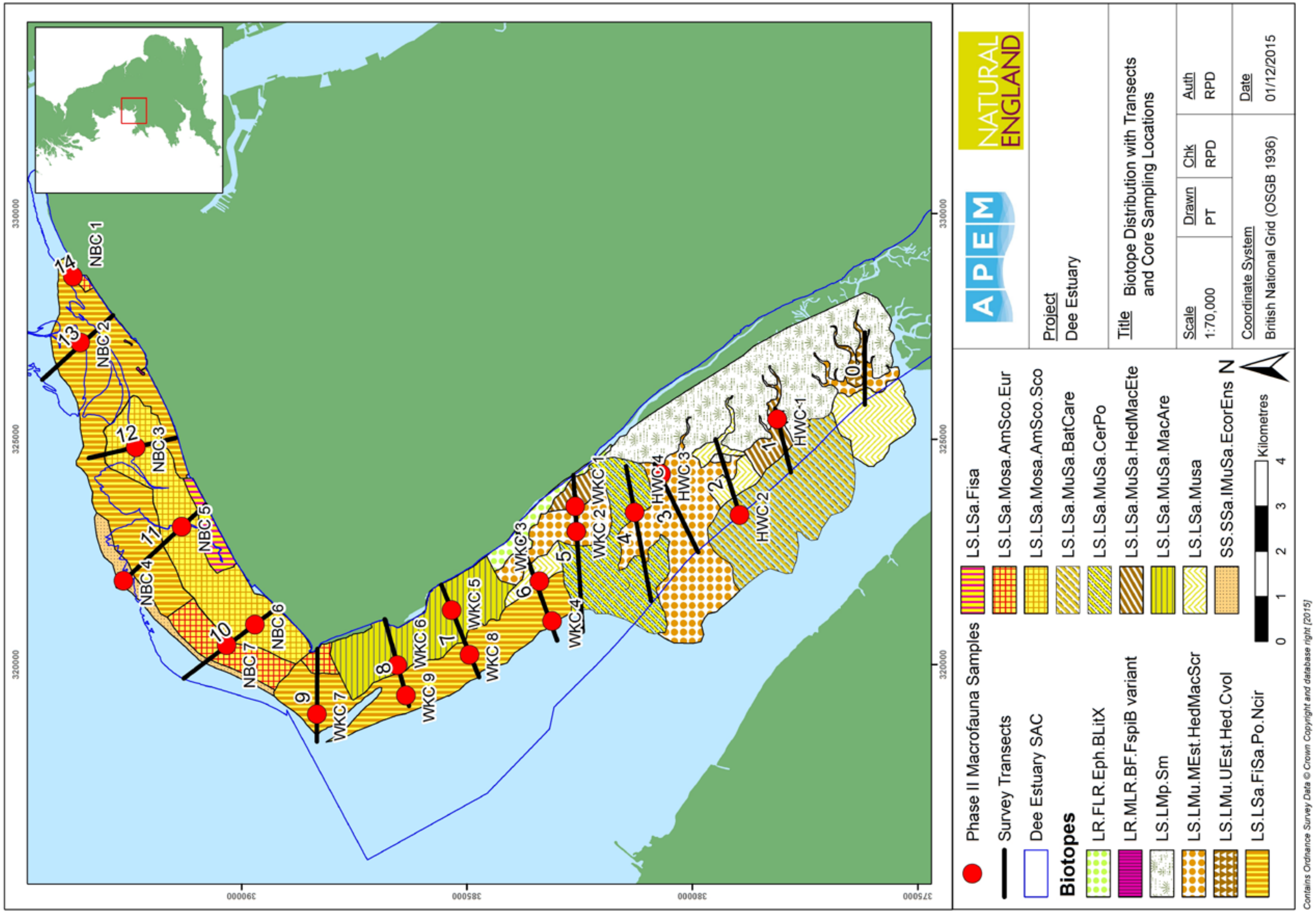


Figure AIII.1. Dee Estuary SAC 2015 biotope distribution and Phase II sample locations. Transects 0 to 4 inner, 5 to 9 middle and 10 to 14 outer estuary sectors.

6.4 Appendix IV. Raw sediment contamination data.

Analyte (mg/kg)	WK Cont 1	HW Cont 1	HW Cont 2	WK Cont 2	NB Cont 1	HW Cont 3
Nitrogen : Dry Wt as N	<200	<200	1330	1350	<200	2920
Mercury : Dry Wt	0.00662	0.0443	0.131	0.106	0.0117	0.281
Aluminium, HF Digest : Dry Wt	12500	23300	42600	34100	14600	63300
Iron, HF Digest : Dry Wt	6490	10300	22000	16700	8510	35000
Arsenic, HF Digest : Dry Wt	5.81	7.53	14.2	9.59	7.32	21
Cadmium, HF Digest : Dry Wt	0.016	0.201	0.24	0.15	0.027	0.389
Chromium, HF Digest : Dry Wt	23.9	24.7	64.5	54.4	24	86.6
Copper, HF Digest : Dry Wt	0.477	4.46	13.8	8.93	0.82	26.7
Lead, HF Digest : Dry Wt	9.33	18.5	34	24.7	9.65	58.8
Lithium, HF Digest : Dry Wt	10.3	17.1	42.8	29.4	10.7	69
Manganese, HF Digest : Dry Wt	175	348	981	629	312	1590
Nickel, HF Digest : Dry Wt	3.43	8.48	21.6	15.3	5.26	35.2
Zinc : HF Digest : Dry Wt	23	107	126	82.9	21.8	242
Hexachlorobenzene : Dry Wt	<0.1	<0.1	0.288	0.219	<0.1	0.433
Hexachlorobutadiene : Dry Wt	<0.1	<0.1	0.128	<0.1	<0.1	0.301
Anthracene : Dry Wt	<1	17.7	21.3	13.2	<1	33.3
Benzo(a)anthracene : Dry Wt	<1	35.4	44.4	30.5	1.29	86.3
Benzo(a)pyrene : Dry Wt	<1	35.3	68.2	47.5	4.49	128
Benzo(ghi)perylene : Dry Wt	<1	20.3	68.9	49.1	4.28	135
Chrysene + Triphenylene : Dry Wt	<3	40.6	65.7	45.2	3.4	120
Fluoranthene : Dry Wt	<1	66.2	90.5	59.9	4.88	162
Indeno(1,2,3-c,d)pyrene : Dry Wt	<1	21.9	59.7	43.3	2.59	125
Naphthalene : Dry Wt	<5	6.6	24	16.9	<5	44.3
Phenanthrene : Dry Wt	<5	16	53.1	35	<5	89.9
Pyrene : Dry Wt	<1	58	89.9	58.1	4.63	157
2,2,4,4,5,5-Hexabromodiphenyl ether : Dry Wt :- {PBDE 153}	<0.02	<0.02	0.088	<0.02	<0.02	0.028
2,2,4,4,5,6-Hexabromodiphenyl ether : Dry Wt :- {PBDE 154}	<0.02	<0.02	0.025	<0.02	<0.02	0.042
2,2,4,4,5-Pentabromodiphenyl ether : Dry Wt :- {PBDE 99}	<0.05	<0.05	0.059	<0.05	<0.05	0.101
2,2,4,4,6-Pentabromodiphenyl ether : Dry Wt :- {PBDE 100}	<0.02	<0.02	0.021	<0.02	<0.02	0.038
2,2,4,4-Tetrabromodiphenyl ether : Dry Wt :- {PBDE 47}	<0.07	<0.07	0.07	<0.07	<0.07	0.13
2,4,4-Tribromodiphenyl ether : Dry Wt :- {PBDE 28}	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
PCB - 028 : Dry Wt	<0.1	<0.1	0.382	0.283	<0.1	0.762
PCB - 052 : Dry Wt	<0.1	<0.1	0.167	0.113	<0.1	0.325
PCB - 101 : Dry Wt	<0.1	<0.1	0.225	0.171	<0.1	0.475
PCB - 118 : Dry Wt	<0.1	<0.1	0.321	0.232	<0.1	0.687
PCB - 138 : Dry Wt	<0.1	<0.1	0.257	0.195	<0.1	0.511
PCB - 153 : Dry Wt	<0.1	<0.1	0.366	0.272	<0.1	0.783
PCB - 180 : Dry Wt	<0.1	<0.1	0.179	0.141	<0.1	0.413
Tributyl Tin : Dry Wt as Cation	<4	<4	<6	<5	<4	<6
Batch no.	20084379	20084379	20084379	20084379	20084379	20084379
Sample Preparation	Homogenised, Jaw Crushed & Sieved to <63µm	Homogenised, Jaw Crushed & Sieved to <63µm	Homogenised, Jaw Crushed & Sieved to <63µm	Homogenised, Jaw Crushed & Sieved to <63µm	Homogenised, Jaw Crushed & Sieved to <63µm	Homogenised, Jaw Crushed & Sieved to <63µm
Dry Solids @ 30°C (%)	81.4	70.4	54.4	59.8	75.4	46.1
No. Accreditation Assessment	2	2	2	2	2	2
Additional Material Present	No additional material	No additional material	No additional material	No additional material	No additional material	No additional material
Drying Method	Air dried at 30°C	Air dried at 30°C	Air dried at 30°C	Air dried at 30°C	Air dried at 30°C	Air dried at 30°C
Rejected Matter Description	No material removed	No material removed	No material removed	No material removed	No material removed	No material removed
Sample Colour	Brown	Brown	Brown	Brown	Brown	Brown
Sample Matrix	Sandy Sediment	Sandy Sediment	Sandy Sediment	Sandy Sediment	Sandy Sediment	Sandy Sediment
Carbon, Organic : Dry Wt as C (%)	<0.200	0.334	1.33	7.77	<0.200	4.36
Sample taken	02/09/2015	17/09/2015	15/09/2015	02/09/2015	01/09/2015	30/08/2015

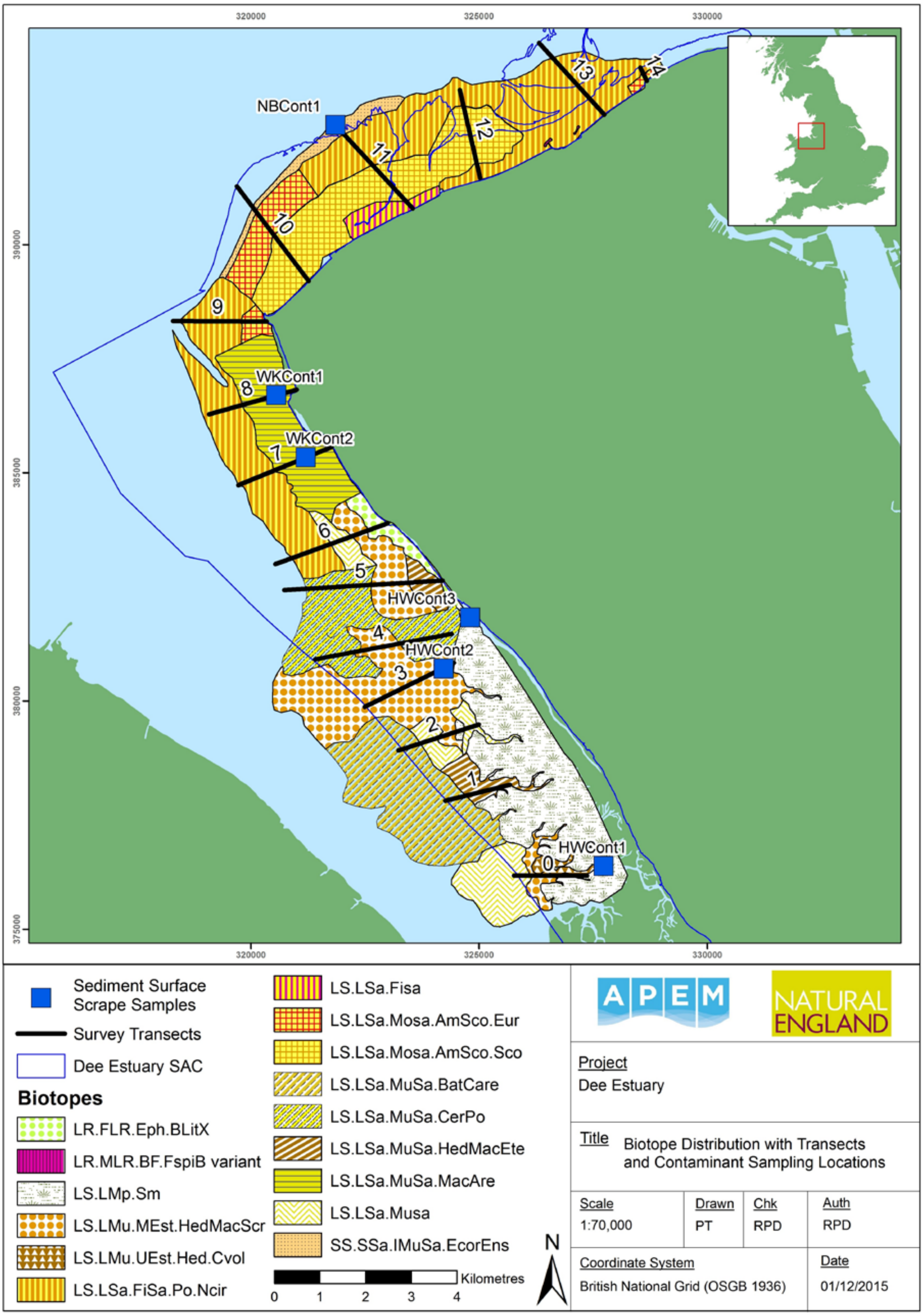
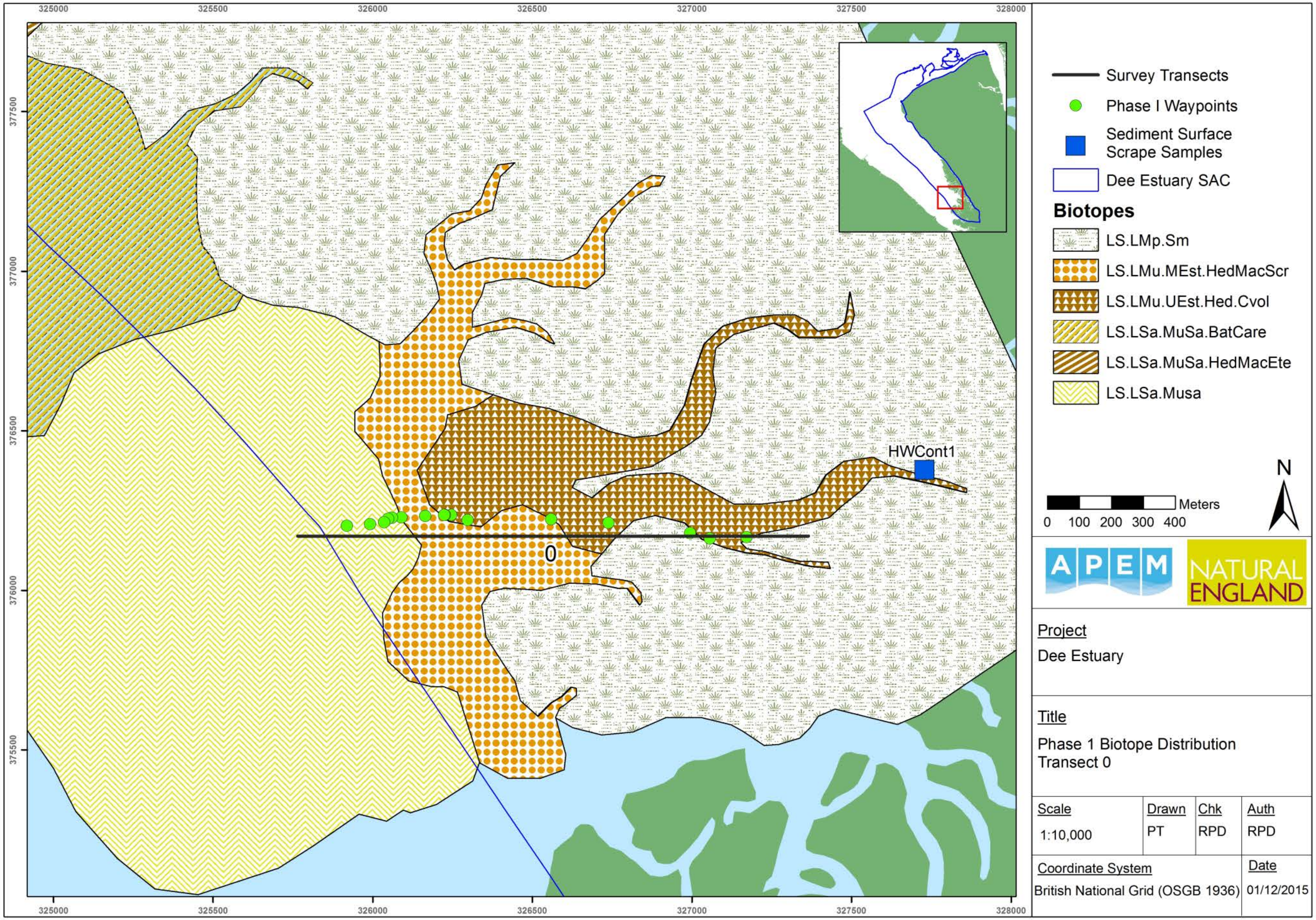


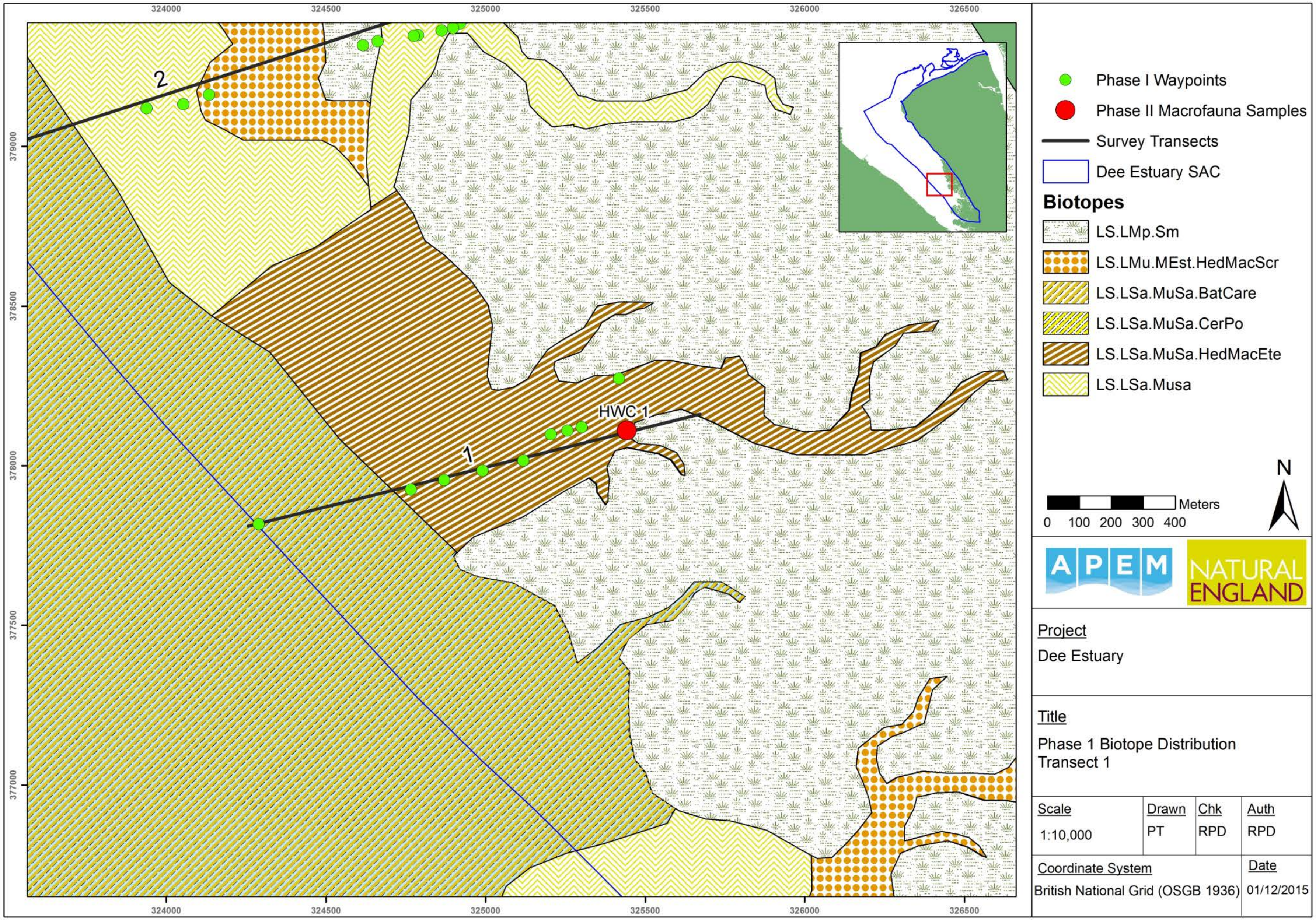
Figure AIV.1. Dee Estuary SAC 2015 biotope distribution and surface scrapes sample locations. Transects 0 to 4 inner, 5 to 9 middle and 10 to 14 outer estuary sectors.

Transect 0

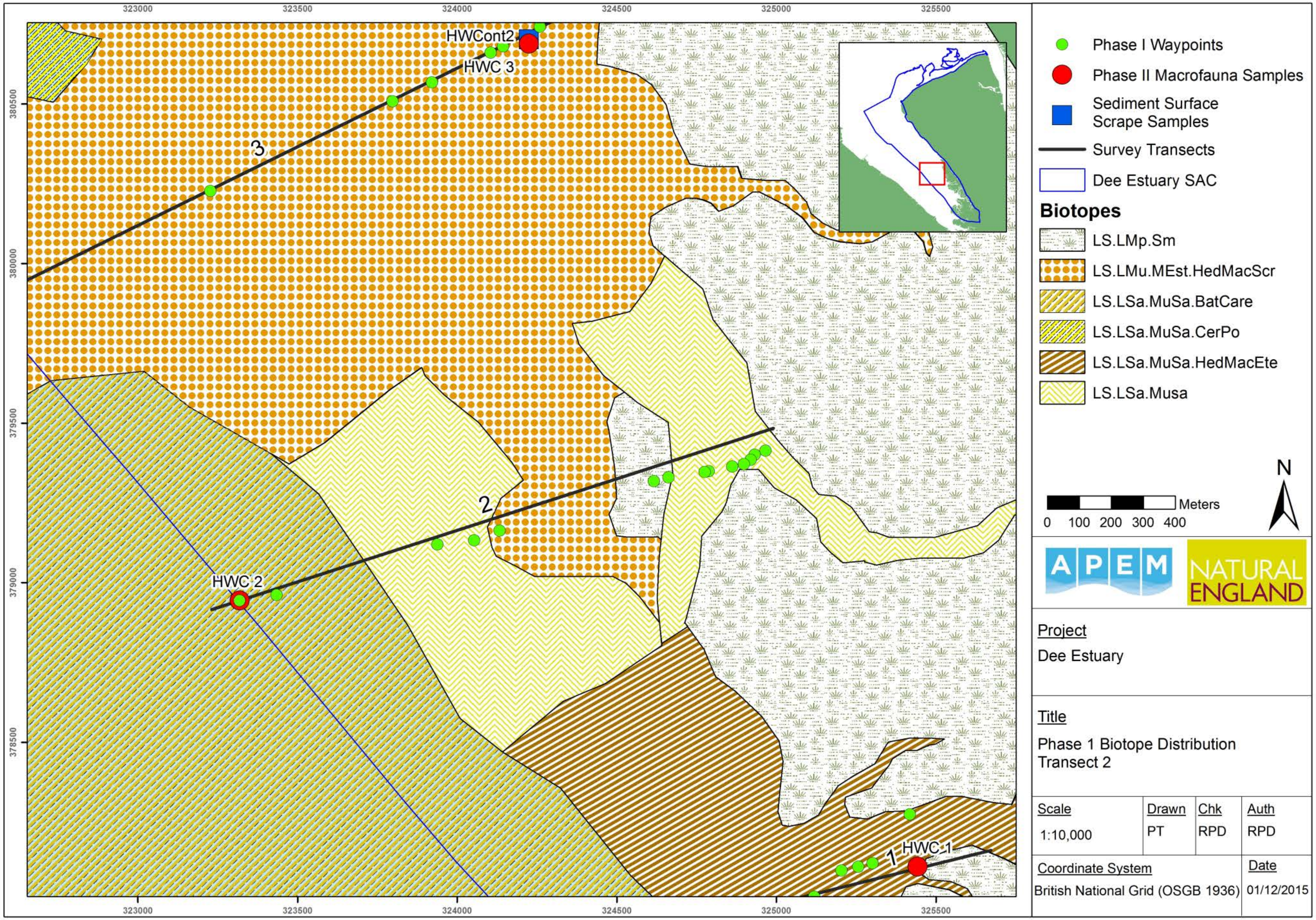
6.5 Appendix V. Biotope distribution maps.



6.5.2 Transect 1

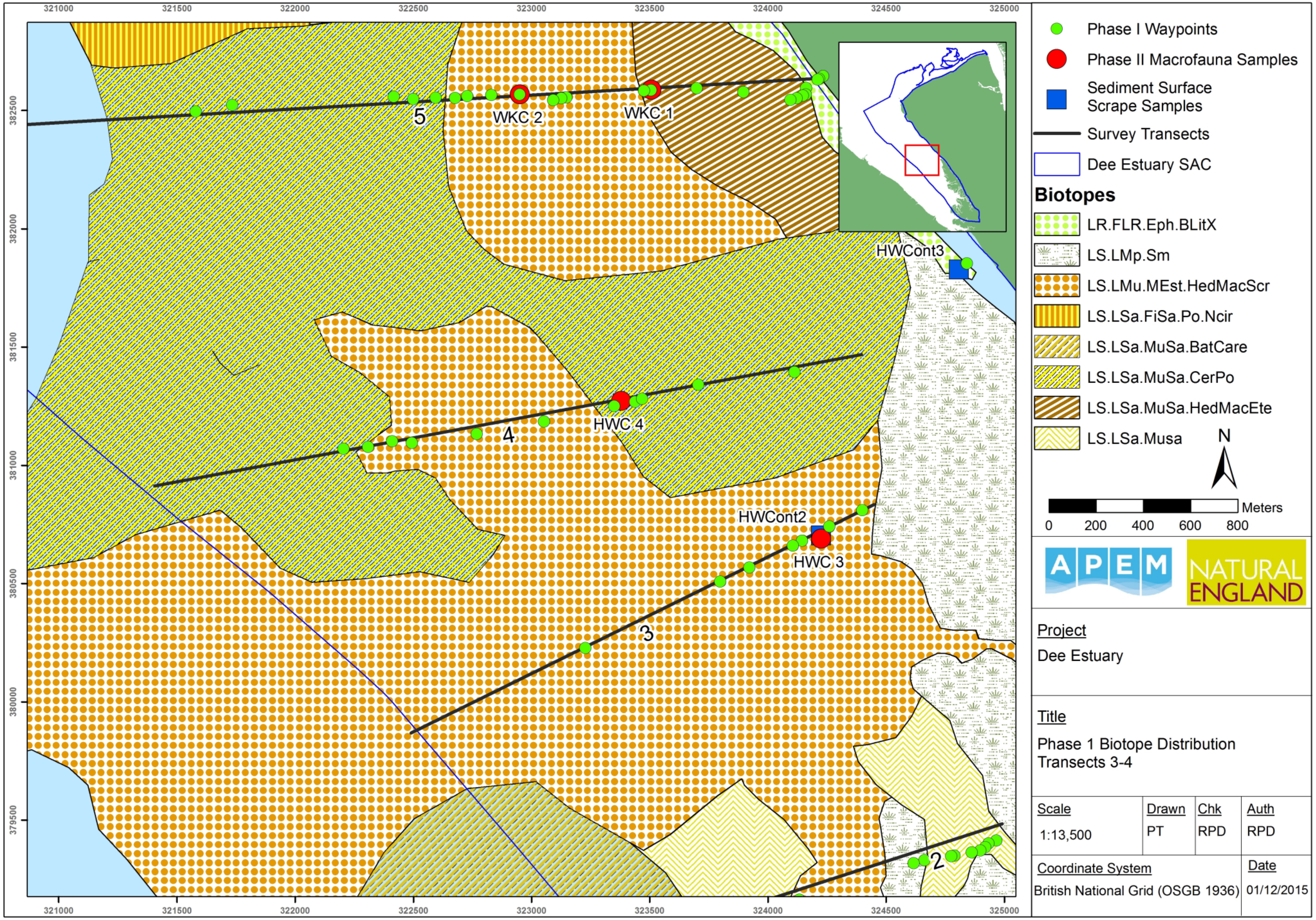


6.5.3 Transect 2

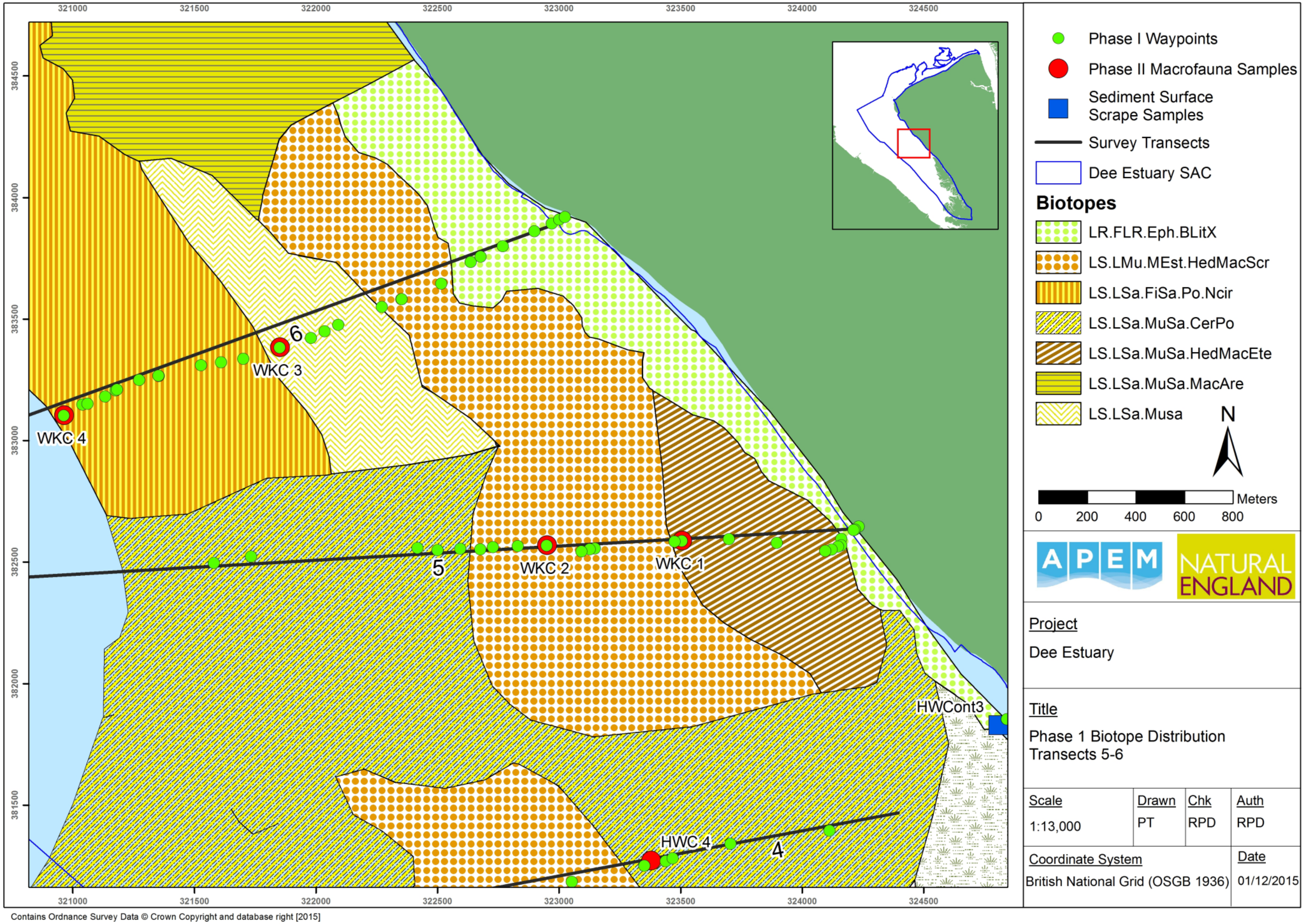


J

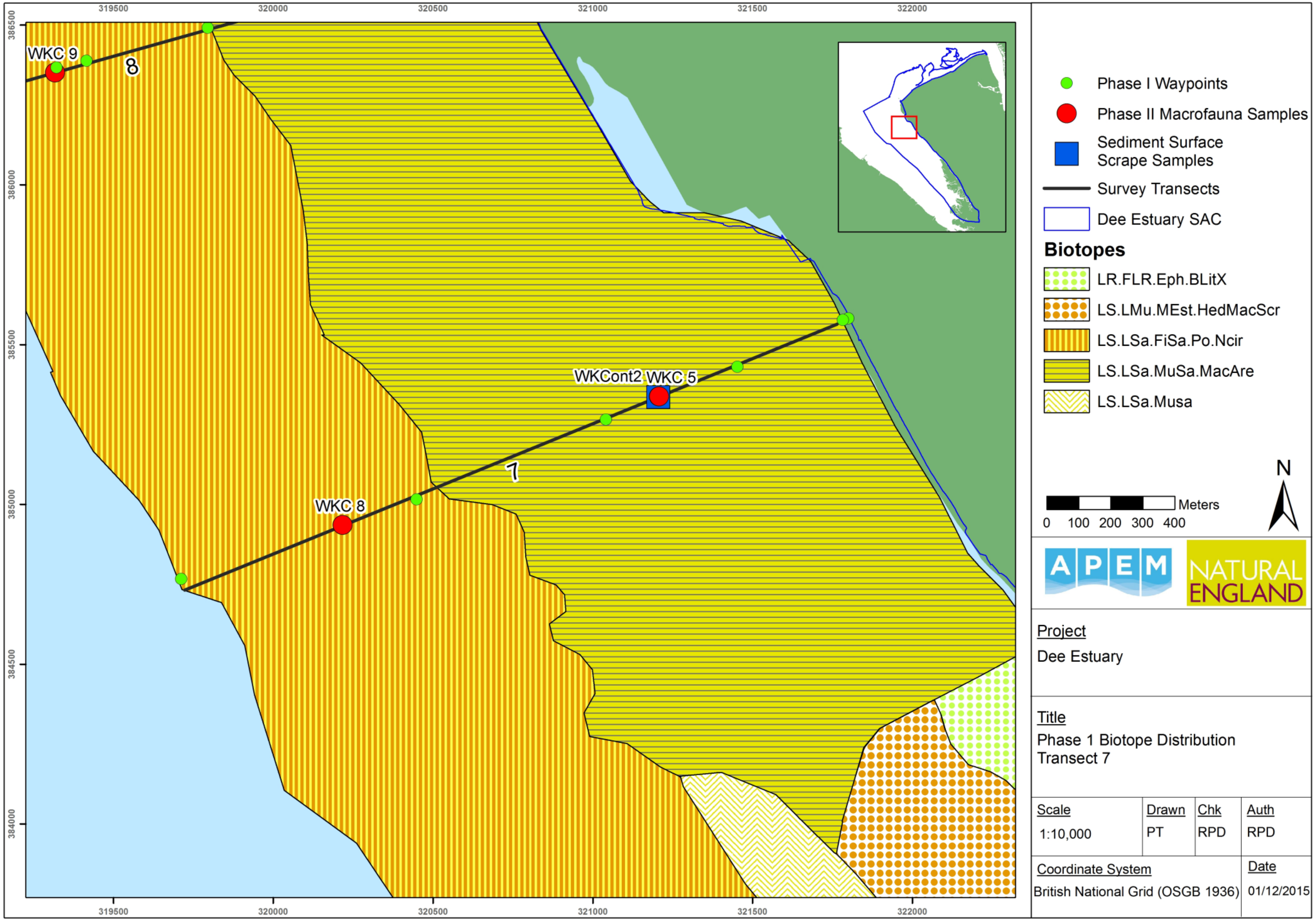
6.5.4 Transects 3-4



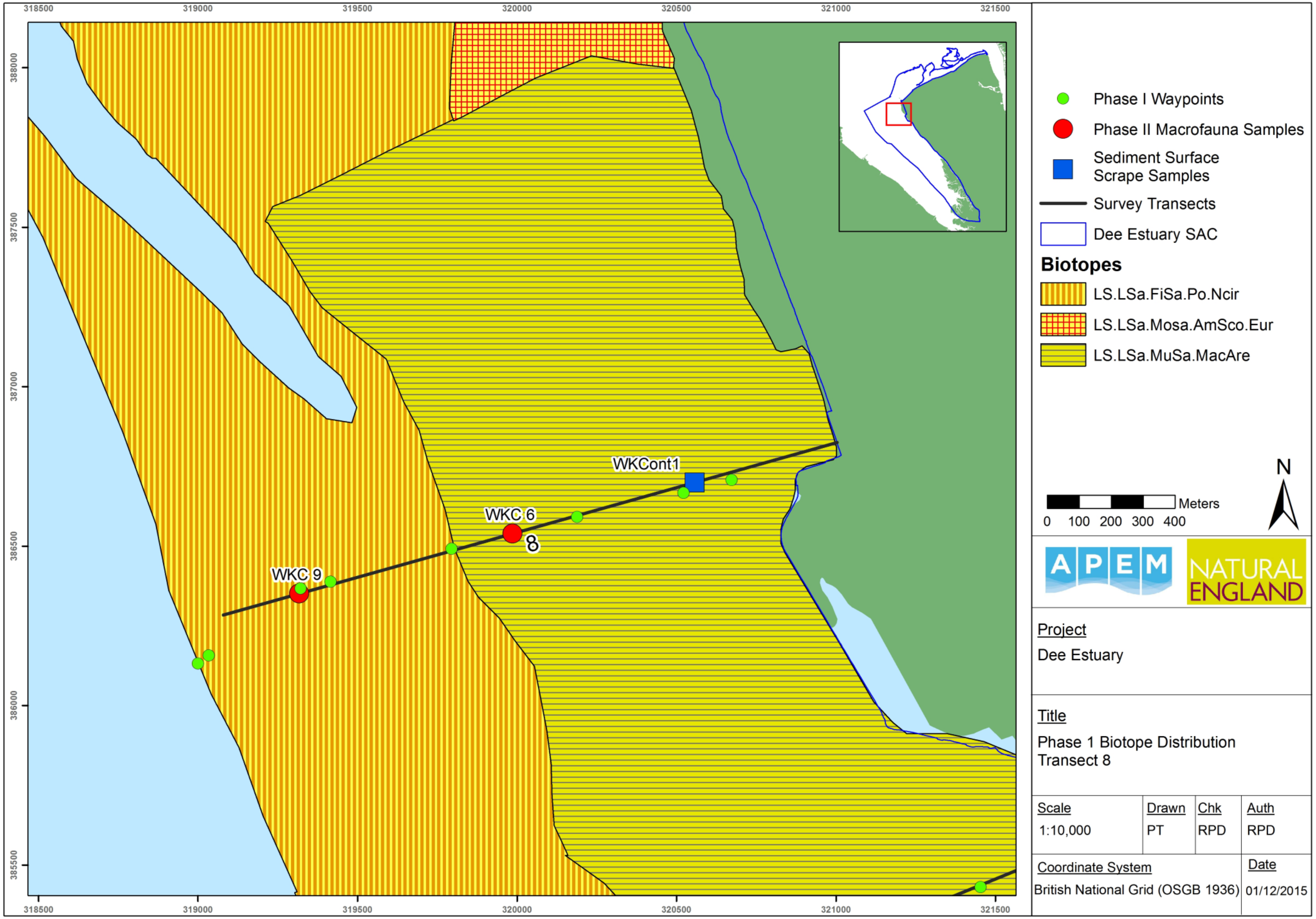
6.5.5 Transects 5-6



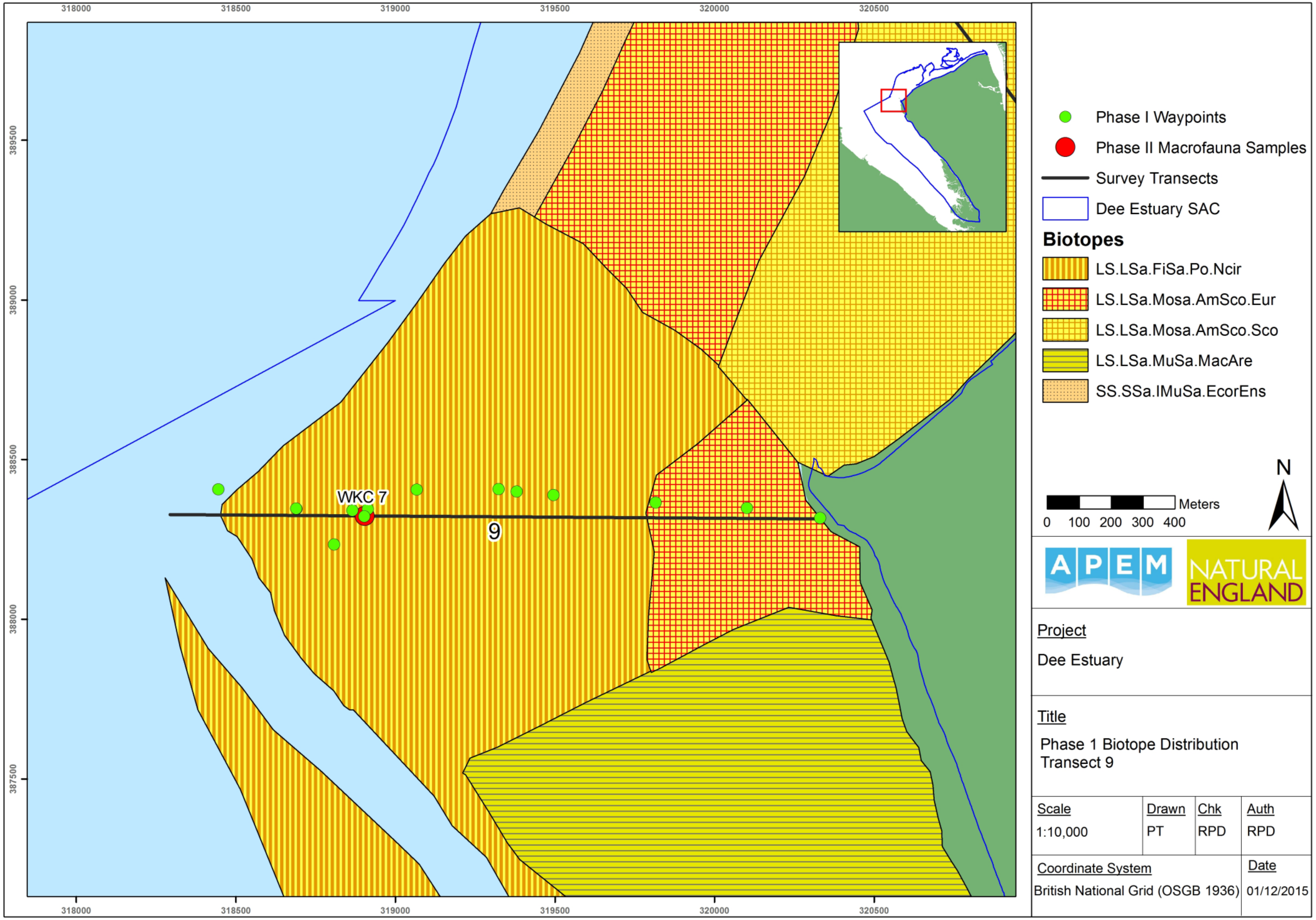
6.5.6 Transect 7



6.5.7 Transect 8

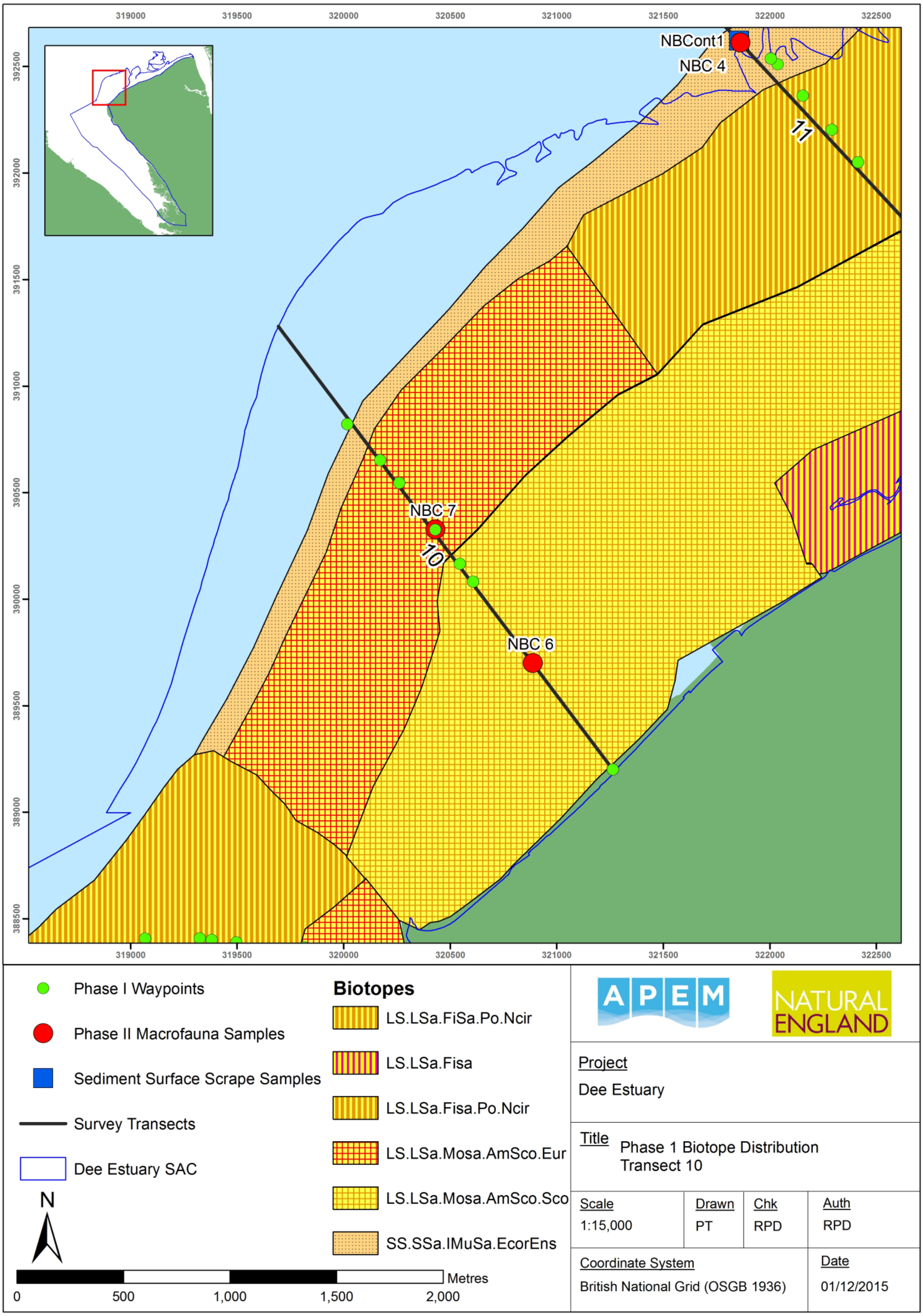


6.5.8 Transect 9

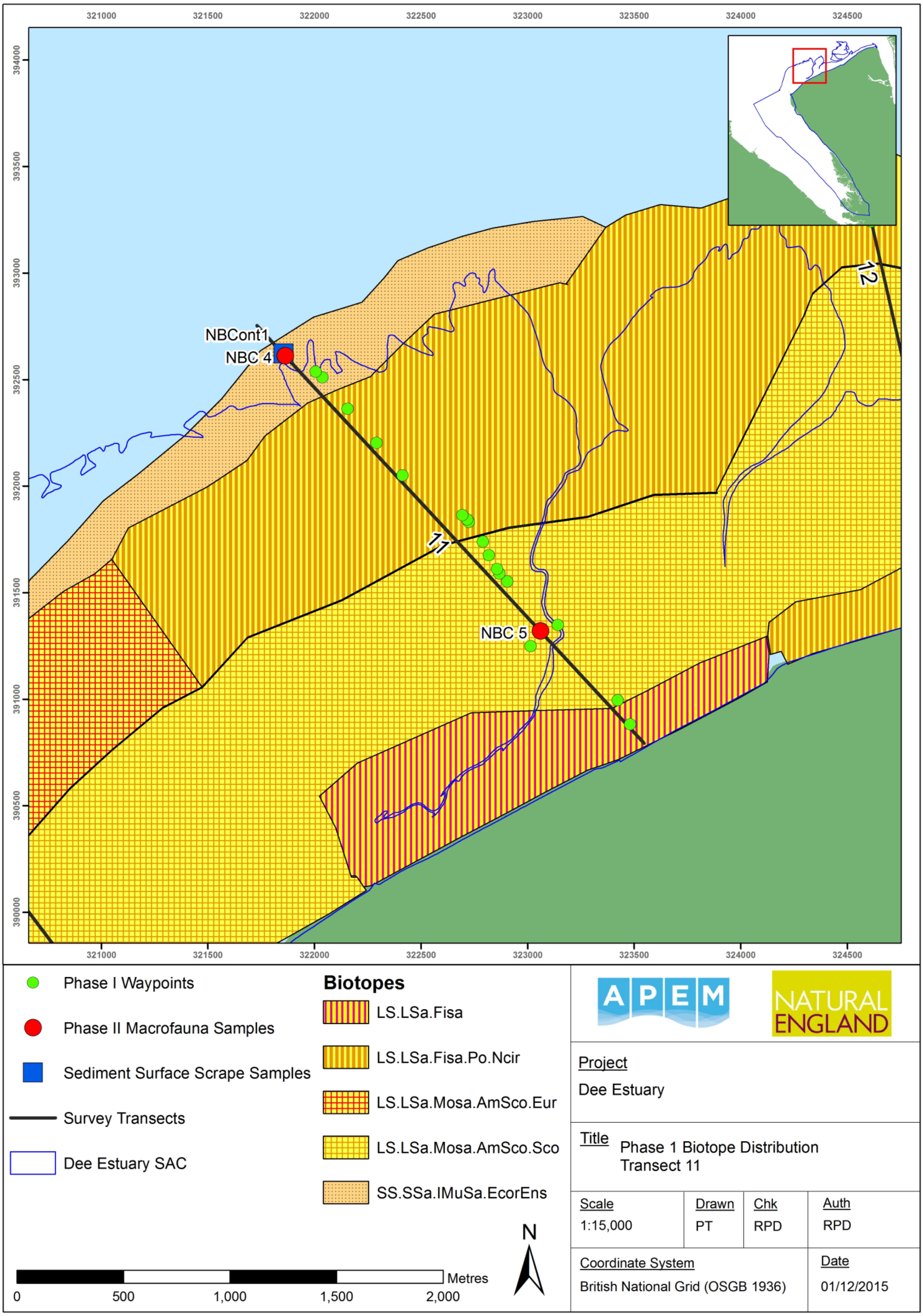


J

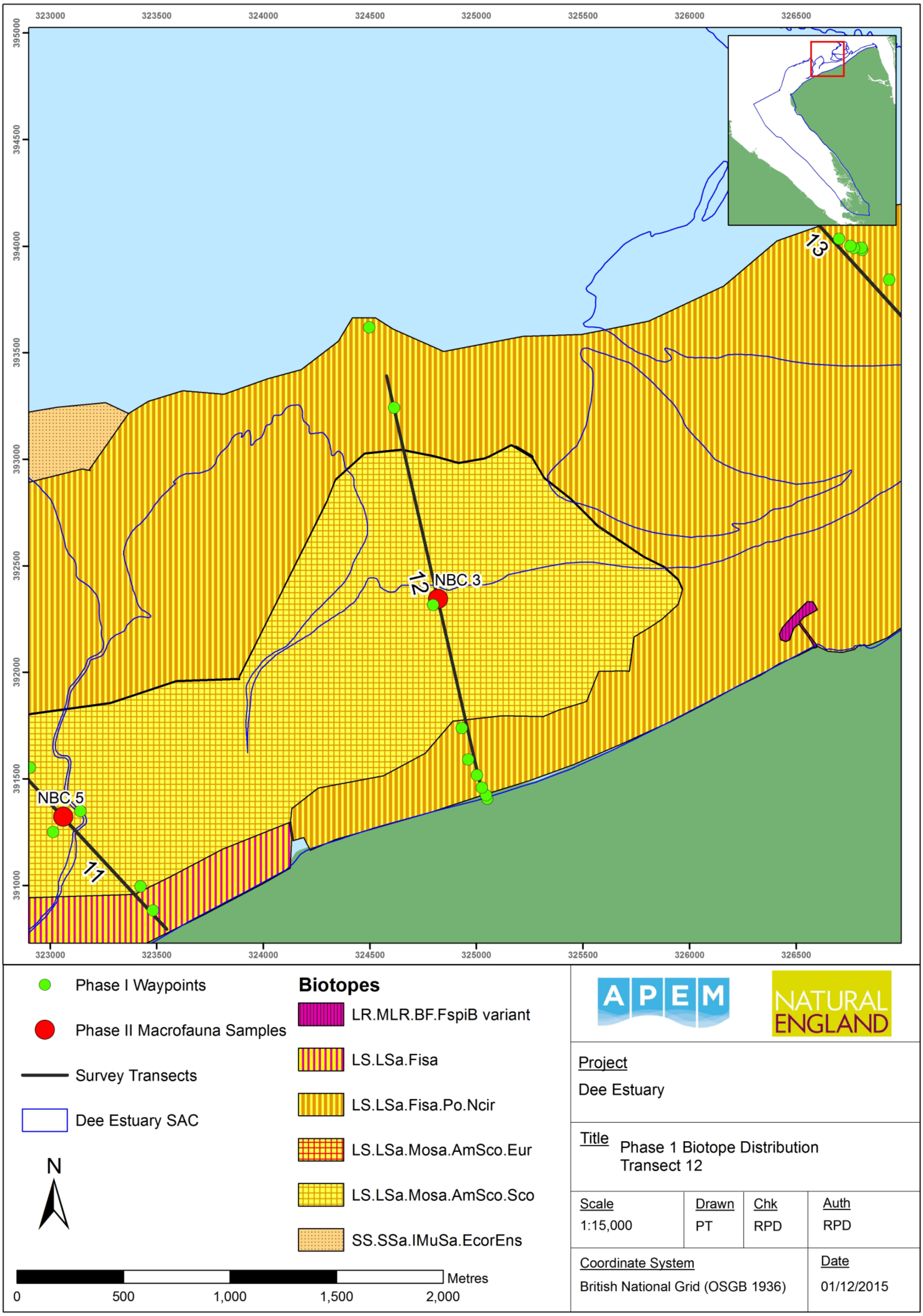
6.5.9 *Transect 10*



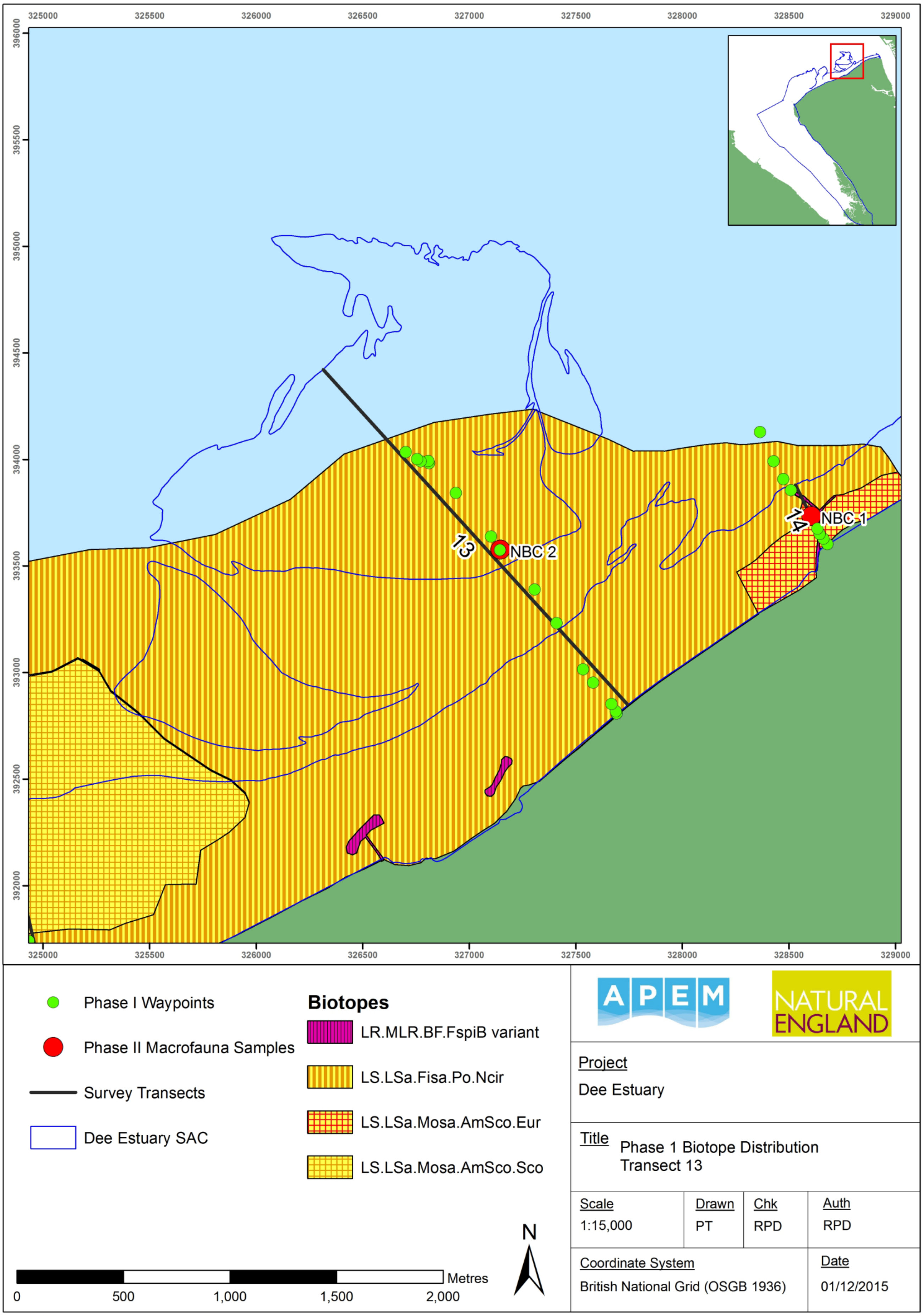
6.5.10 Transect 11



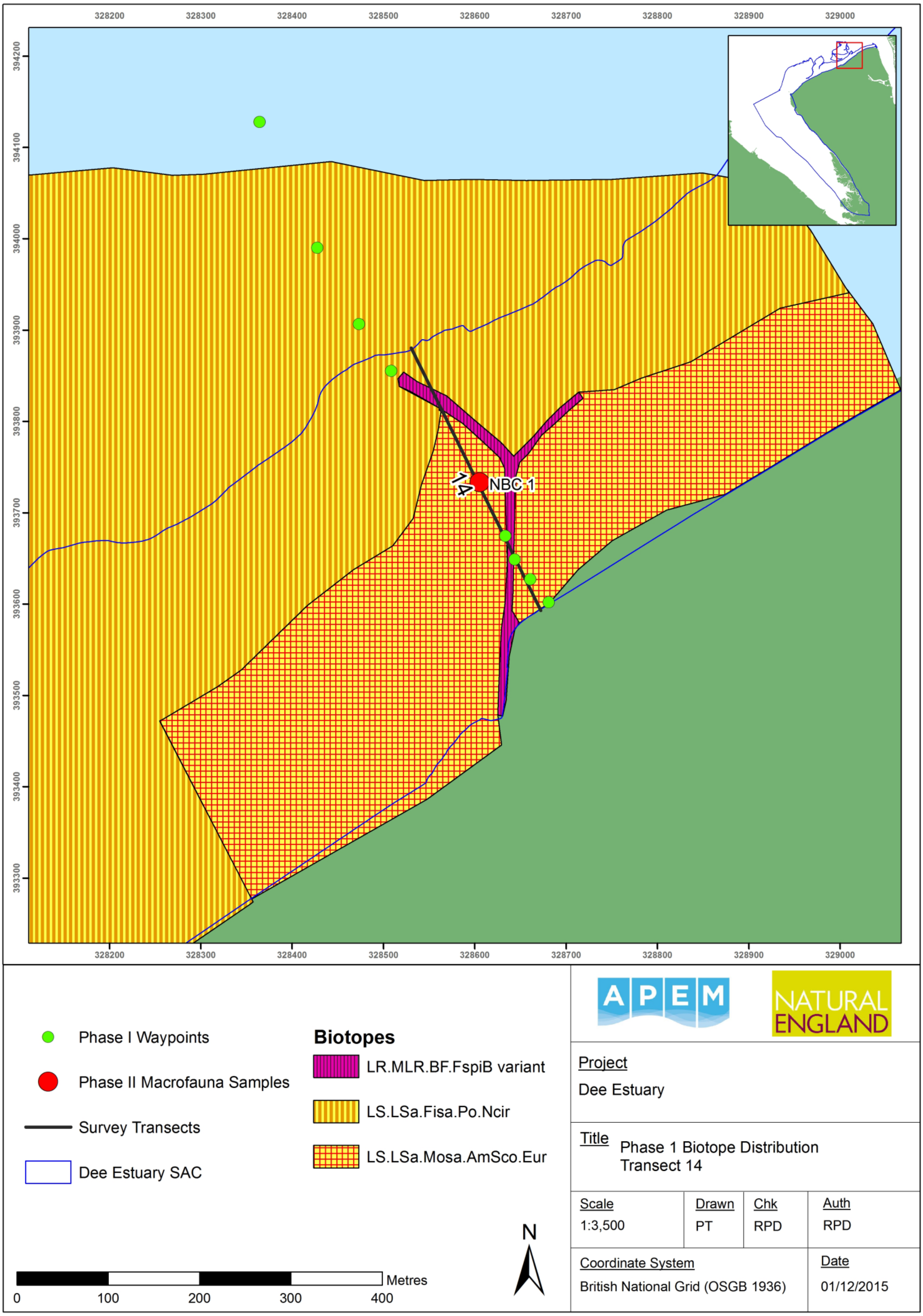
6.5.11 Transect 12



6.5.12 Transect 13



6.5.13 *Transect 14*



Further information

Natural England evidence can be downloaded from our **Access to Evidence Catalogue**. For more information about Natural England and our work see **Gov.UK**. For any queries contact the Natural England Enquiry Service on 0300 060 3900 or e-mail **enquiries@naturalengland.org.uk**.

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